THE POSITION OF

ASPEN (POPULUS TREMULA) IN

BRITISH SILVICULTURE

by

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PREFACE

This thesis has been written as part fulfilment of the requirements for the Post Graduate Honours Forestry Degree Course at the University of Edinburgh.

The aspen has so far been rather a neglected tree species in British silviculture, and it has been a pleasure to undertake this work which has shown that there are silvicultural and economic potentialities for the aspen in Britain.

The thesis is divided into five parts, the first of which consists of a detailed account of the aspen tree, its general growth habits, uses and diseases.

The second part deals with the present position of the aspen in British forestry. This account is based on the results of eight weeks of detailed field studies, and also visits to estates in which aspen culture has been practised, in various parts of Britain, but chiefly in the Spey Valley and Great Glen areas of Scotland. Everywhere the aspen was found to be poor in growth and form.

The third part deals similarly with the present position of aspen in Norwegian forestry. In Southern Norway aspen is now the major economic leaf-tree species. This has been brought about relatively recently through the opening up of an outlet for smaller sizes of aspen timber in the manufacture of pulp, paper and wall-board; the larger sizes have always been used for match making. My three weeks study of the aspen in Norway clearly confirmed the possibilities of its growth and utilization. (In North America, the closely related American aspen is also treated as economically valuable, it being utilized in many ways).

In the fourth part suggestions are made for methods

of increased and better aspen culture in Britain. There seems to be no reason why aspen timber could not be utilized in all sizes in Britain, as is the case in Norway, thus making treatment of the species by thinnings economic, and ultimately increasing the value of the timber.

Part five consists of a general summary of the work and some recommendations are given. The main recommendations are: - To obtain and use a more suitable strain of aspen than that found growing naturally in Britain, through provenance trials. To utilize natural sucker growth initially where practicable. To use aspen as a nurse species for preclimax or climax species and to treat all aspen growth by a system of light thinnings.

At the end of the thesis there are ten appendices which provide detailed data on various subjects mentioned in the text.

I wish to record my thanks to Professor M.L. Anderson, M.C., M.A., D.Sc., for suggesting the subject for the thesis and for his guidance in preliminary discussions on the subject.

I wish also to express my thanks to all who conducted me round their aspen woodlands, both in Britain and in Norway. Especially to Professor Ola Børset and his assistant, Forstkandidat Sigmund Huse of the Frølich's Foundation and the Institutt fur Skogshjøtsel, Vollebekk, who made me welcome in Norway and who so ably conducted me round some of the aspen occurrences in Southern Norway and supplied me with much data and literature on the Norwegian aspen.

Whilst the majority of the photographs used in illustration of the text are my own, I wish to record my thanks to Olav Lovland of Haugsjø for photographs 107 and 109 and to J.M. Powell, B.Sc., for photograph 16 and for providing the Canadian aspen leaves for photograph 9.

[redacted]

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PART I.

THE ASPEN - A GENERAL DESCRIPTION OF THE TREE, ITS GROWTH HABITS AND USES.

I.1. GENERAL DESCRIPTION OF THE ASPEN

The aspen is a member of the genus Populus and has the specific name Populus tremula L. It is a short lived tree, rarely attaining an age of a hundred years. In Britain it is a small tree, normally between thirty and forty five feet in height, with a girth at breast height of up to four and a half feet. Under favourable conditions a height of seventy feet and girth of five or six feet is sometimes obtained. In Scandinavia, Russia and the Baltic States, however, the tree is somewhat larger and a height of a hundred feet is not exceptional.

The stem, as a rule, is straight and of good form, having little taper. In some cases there is a slight buttressing at the base. When growing well and vigorously the tree has a few slender ascending branches which form a thin crown.

The general shape and characteristics of the aspen can be seen in Photograph 1. This shows a small group of aspens which have grown up naturally at the edge of a wood.

Aspen bark is of a grey-or yellowish-green colour, smooth and thin when young. It is characterised by a whitish bloom which comes off on the hand when rubbed. This white chalk-like material is made up of dead bark cells. In the bark, rhombic-shaped lenticels appear as the tree becomes older. These tend to give the bark a mottled appearance which is clearly shown in Photograph 2. in which the bark formation around a small twig is also shown.

Photograph 3. The bark of old aspen showing the deep furrows. Idd, Norway.

Photograph 4. Lichen-covered bark, typical of most British aspen. Grantown-on-Spey.

Photograph 5. A comparison between the crowns of birch (left) and aspen (right). Stange, Norway.

With increasing age the lenticels increase in size and eventually, coupled with a general cracking of the bark surface owing to expansion, they tend to coalesce and deep bark fissures are formed. The bark eventually becomes thick, deeply furrowed and of a dark grey colour, particularly near the base. This is shown in Photograph 3. The poorer the site for aspen the higher these furrows tend to extend. Similarly it is noticeable that the number and size of the lenticels increases on poor sites. Often, when badly sited or when the tree is very unhealthy the bark becomes flecked with highly coloured lichens such as the yellow wall lichen Xanthoria parietina, the green lichen Physcia ciliaris and the dark brownish-green Collema vespertilio. Lichen-covered bark, so common a characteristic of British aspen, is shown in Photograph 4.

The light crown is commonly perched a considerable way up the stem, even in open situations. The branches are scantily foliaged and therefore the crown casts but little shade. The density of the crowns of birch and aspen growing side by side, can be seen in Photograph 5.

The lower branches and branchlets die off when shaded, thus the stems are pruned naturally. Unhealthy trees, however, tend to retain more branches, and their dead branches for a longer time, than healthy vigorous trees. Consequently the unhealthy trees tend to have heavier crowns.

The tree has a very limited power of emitting additional new shoots from its branches, stem or stump. Thus, in this respect the aspen is very largely dependent upon the roots. These have a very great capacity for vegetative reproduction, producing abundant suckers. It is primarily by this means that the aspen spreads naturally and therefore clones of aspen are readily produced. It is the abundant sucker growth found around large stems which accounts for the scrub-like growth commonly associated with aspen.

Photograph 6. An aspen root bearing a typical root sucker. The sucker has already started to produce its own root system.

Photograph 7. An exceptionally large aspen root clinging to the rocks. This indicates the extent to which aspen roots will develop. Haugsjå, Norway

The root system is shallow, seldom being deeper than two feet, and consisting of several main roots which divide into wide-spreading rootlets growing out just beneath the soil surface for a considerable distance. Aspen roots have been found to extend up to forty yards from some large specimens (Tkachenko 34). The root suckers, for the most part, grow from roots of about a quarter to one half inch in thickness which lie in the forest litter, on the surface of the mineral soil or at depths of up to about six inches. From time to time suckers also appear on deeper roots and also from those of greater thickness. Photograph 6. shows a typical young sucker and the way it has grown from the horizontal root, whilst Photograph 7. shows the extent to which the roots can grow in exceptional circumstances. Even on this large root, suckers are produced. The development of suckers is facilitated by wounding the roots. This often occurs naturally as the roots are situated so near, or even on the soil surface. Root suckers may develop for a period of several years after a tree has been felled. The suckers generally grow very fast but are extremely palatable to animals and hence are often eaten back. In some countries grazing is used as a means of controlling aspen suckers where this becomes necessary.

Young aspen branches are relatively strong and pliant and are not easy to break, but there is generally weakness at the point where they meet the stem and hence, in high winds some branches may be completely broken off. As the branches grow older they become more susceptible to wind-break and to rime damage and the crowns of old trees are often extremely broken by these means. All breakages and other wounds facilitate attack by fungi.

The young branchlets are glabrous, rounded and shining, with orange lenticels. The vegetative buds,

Photograph 8. An aspen twig with vegetative buds.

Photograph 9. A variety of shapes and sizes of aspen leaves:-

A. Young Populus tremuloides leaves from Canada.
B. Fully grown P. tremula leaves.
C. A small root sucker showing the variation in it's leaves.
D. A P. tremuloides-sucker leaf from Canada.

which are arranged spirally are of a shining brown colour, oval in shape with a sharply pointed apex. The buds are very slightly viscid with ciliate scales, the uppermost of which are slightly pubescent. Buds on the long shoots are somewhat pressed to the twigs but on the short side shoots are clustered. Photograph 8. shows a typical twig with vegetative buds. The florescent buds are similar to the vegetative buds but are shorter and fatter.

The stipulate aspen leaves vary somewhat in colour. Often the newly flushed leaves are of a reddish-or yellowish-brown colour, but also pale yellowish-green leaves are common. As they grow older the leaves become a bright greyish-green. They are suborbicular, variable in size from half an inch to four inches in diameter but averaging one and a half to two inches (the leaves of the giant polyploid aspens, and occasionally odd leaves on new shoots are very much larger, being six to seven inches in diameter). Aspen leaves have a thin texture, are truncate or subcordate at the base, rounded or acute at the apex. The leaf margin has a translucent border, and a few rounded, small teeth. The great variety in shape and size of aspen leaves is indicated by the selection in Photograph 9. The leaves are tomentose when young, speedily becoming glaborous on both surfaces, pale or glaucous beneath, with often the remains of down on the underside near the base. The venation is pseudo five-palmate. At the base of the terminal leaves of long, vigorous shoots there are two cup-shaped glands; their function is obscure. The petioles are extremely slender and unusually long, being as long or longer than the blade; they are laterally compressed or flatten ed and in consequence cannot support the leaf in a horizontal position, as shown in Photographs 10 and 11, where the leaves hang down in typical fashion. The least breath of wind will cause the leaves to move and produce the characteristic trembling of the

Photograph 10. Young aspen trees, which show the early form and the characteristic way the leaves hang down. Haugsjå, Norway.

Photograph 11. An aspen twig showing the typical hanging leaves.

foliage. This peculiarity has obtained for the aspen the unenviable distinction of being selected as the poetical emblem of restlessness, inconstancy and fear. Also from it arise local names such as TAFODEN MERCHED in North Wales and CHENGEY-NY-MRAANE in the Isle of Man - both meaning "Women's tongues". The leaves on young plants, on sucker shoots, and in rare cases on sporadic branches of adult trees, are of a different shape and are sometimes larger. They are ovate or rounded-triangular, accuminate at the apex and truncate or cordate at the base. They are greyish or woolly beneath, glandular-serrate with short pubescent petioles. The leaves of aspen turn yellow in the Autumn, falling in October. They become dark brown or black when decaying. The leaf scars left on the twigs are broadly crescent-shaped with three regularly placed vascular bundle scars.

The aspen, as all other pop-lars, is dioecious, the different sexes appearing on different trees. The pendulant catkins appear in late March and April before the leaves.

Generally the male catkins appear before the female catkins. Fertilization, of course, depends on whether male and female trees occur close together. It often happens that all the trees in one area are of one sex and hence fertilization is a rare occurrence.

Fertilization and seed formation is dependent on the production of catkins. These do not occur in equal abundance each year, as there are definite good and bad years. It has been found that rich flowering years occur in the spring following a hot July. If the weather in July is not good, a poor aspen flowering can be expected in the following year. July in 1955 was a hot month and 1956 was therefore a good aspen flowering year, but July of 1956 was cool and this resulted in a very poor aspen flowering in 1957.

A female tree possessing abundant catkins is shown in Photograph 12. The catkins here are at a stage about

Photograph 12. A female aspen tree bearing abundant catkins. Haugsjå, Norway.

Photograph 13. Female catkins at the time of pollenation.

Photograph 14. Female catkins at the time of seed-dehiscence. The white woolly pappus is clearly visible.

five days before dehiscence.

The catkins (illustrated in Photograph 13) vary in size between one and four inches. They are sub-sessile, densely tomentose with white or grey long straight hairs given off from the deeply lobed, obovate catkin scales. The axis of the catkin is pubescent. The flowers are dense and numerous on very short pilose pedicels. The male flower is hidden behind the catkin scale which subtends it. It consists of a disc which carries numerous stamens, the anthers of which are of a purplish-red colour. The female flower also consists of a cup-like disc, on which is situated the one-celled, glabrous ovary with its short style and two stigmas of a purplish-red colour. Each stigmata is divided into four widely dilated curving arms. Red tints, therefore, prevail in both male and female catkins. The fruit is a two-valved capsule which splits to dehisce the minute yellowish seeds, each of which carries a tuft of hairs, the pappus. The catkins at this stage appear woolly, they are illustrated in Photograph 14. The pappus assists in the spread of the seeds which are themselves extremely light and are therefore easily carried relatively great distances by the wind or in the water of either streams or run-off. The seeds are shed during May. The aspen normally begins to set seed at an age of twenty to thirty years.

In the aspen, as in many other dioecious species, the phenomenon of parthenocarpia often occurs, that is, the fruit form normally, but contain no viable seeds as pollination and fertilization have not occurred. It is important that the seeds reach a suitable germination bed quickly, as they remain viable for a few weeks only.

It has generally been thought that aspen seed remains viable for only three or four days, but experiments in Norway (Frølich's Foundation) have shown that seeds stored at room temperature keep their germinative power

for some weeks. Newly harvested aspen seeds have a very high germination power, almost invariably over 80% and in most cases over 90%. After 30 days the average germination power is between 30% and 83% and after 60 days between one and 58%, although there are considerable differences from one year to the next and between seeds from different mother trees (6). Thus, given the right conditions, aspen will germinate quite freely some time after dehiscence, but in nature it is unlikely that more than one in a thousand, seeds germinate and few of the young seedlings become established. It is obvious that other factors interfere and reduce the amount of seed. Considerable damage is done by insects and fungi, whilst the seed is still in the capsules. In Russia (Tkachenko 34) aspen seed in nurseries has been completely destroyed by ants and it is possible that these animals also destroy a great deal of aspen seed in the wild.

The seedlings, which are rare in nature, are extremely small, furnished with two brownish-green, somewhat heart-shaped and fleshy cotyledons. They appear where there is a guarantee of satisfactory and constant moisture supplies in the actual surface layers of the soil. Under conditions of excessive moisture, if seedlings should appear, they quickly die off.

It is generally considered, although definite data is lacking, that aspen grown from sucker shoots seldom attains the same development as when grown from seed. Even in the pole-stage of growth the former shows signs of decreased vitality (2). However, as indicated above, natural regeneration by seeding is rare and hence regeneration by means of root suckers assumes the most important rôle. Suckers appear to be the primary means of reproduction in Britain, indeed Salisbury (31) states that the aspen in Britain never produces fertile seeds and owes its

frequency and success to vegetative propogation by root shoots, which, having the resources of the parent plant to draw upon, can grow up successfully even amongst tall and dense vegetation. This statement is untrue as there are many definite instances of trees derived from seed. Also, catkins taken from trees have produced viable seed which has been used in nurseries (15). However, reproduction by means of suckers is by far the major means in Britain.

I. 2. VARIETIES AND RACES OF THE ASPEN

The aspen, in the wild state, displays considerable variation in the shape, size and colour of the leaf and in the amount of pubescence on the branchlets and leaves. Hence several varieties have been named. Different races or strains of the aspen also exist and show differing growth and form. The principal varieties that have been found are:

(a) Populus tremula var freyni. This variety has rhombic-shaped leaves cuneate at the base, ciliate and pubescent on the underside when young. It has been found extensively in Central France and Prussia and has not been found in Britain.

(b) Populus tremula var pendula (Loudon). The Weeping Aspen. This is a male form only. It has stiff, pendulous branches. It is most commonly seen as a lawn tree grafted on to Populus canescens stock. It is valued for its great wealth of grey-purplish catkins produced in early spring and is one of the most conspicuous and beautiful of the early flowering trees.

(c) Populus tremula var purpurea. This is a female tree possessing leaves with a purplish tinge which is not very marked and does not seem to differ from the type.

(d) Populus tremula var villosa (Eyme), The Downy Aspen. This is a form with shoots pubescent until the second year and the leaves at first densely pubescent with long silky hairs, which are more or less persistent in summer. This variety is fairly common.

Little is known of the different races, but mountain and lowland, and other races have been described in some European countries.

A "saline" aspen is described by Krupenikov (21).

This race appears to have developed in insular woods in the north western Kazakhstan where a strong progressive salinification of the upper horizon of the soil is taking place. The "saline" aspen is a dwarfed form with thicker, more succulent leaves which are of a deeper green colour than the normal aspen leaf.

In Sweden according to Sylvén (33) two distinct types of aspen have been found to exist, these are connected with photoperiodism. There is a northern long day type and a southern short day type. The former is unsuitable for southern conditions, where it grows poorly and the latter is insufficiently winter-hardy for the north where, however, it grows much taller.

Numerous spontaneous occurrences of triploid (3x = 57 chromosomes) and polyploid aspens have been recorded in the Scandinavian countries and these "sports" are spreading in clones by suckers. These trees, with increased numbers of chromosomes, show very rapid growth and the leaves are abnormally large. A giant triploid aspen near Helsinki consists of a clone of nine stems in which the largest is 11 years old and 11.2m. (36.8 feet) high. Such growth indicates that selective breeding and possibly hybridisation will very favourably increase the growth rate and form of the aspen.

I.3. BOTANICAL POSITION AND GEOGRAPHICAL DISTRIBUTION OF THE ASPEN.

The genus Populus together with the genus Salix form the family Salicaceae which is characterized by the fact that its members are dioecious, and the flowers are extremely simple as they possess no petals. The flowers are borne in catkins which appear early in the year, generally before the leaves. The difference between Populus and Salix is not very marked: Populus has pendulous catkins, no nectaries and the stamens and ovary are borne on a cup-shaped disc. The buds have several scales, whereas Salix has upright catkins, nectaries but no floral disc and the buds have a single scale.

The genus Populus includes six sections which are shown in the following table together with their geographical distribution and the principal component species: -

TABLE 1. The sections of the genus Populus with the geographical distribution of the major component species. After Peace (27).

Section	Europe & N. Africa to W. Asia.	North America	Eastern Asia.
LEUCE (White poplars)	alba		alba
TREMULAE (Aspens)	tremula	tremuloides grandidentata	tremula sieboldii
TACAMAHACA (Balsam poplars)		tacamahaca trichocarpa candicans	laurifolia yunnanensis maximowiczii simonii
AIGEIROS (Black poplars)	nigra and vars	deltoides and vars	
LEUCOIDES		heterophylla	lasiocarpa
TURANGA	denhardtiorum euphratica		

It will be seen that Populus tremula L is a member of the section Tremulae whose members are found in a complete ring around the northern hemisphere.

The four aspens may be distinguished readily and a key is shown in Appendix II.

The so-called European aspen (aspen) - Populus tremula L. is considered to have a wider distribution than any other tree covering 140 degrees of Longitude and 35 degrees of Latitude and extending from Lapland to North Africa and from Ireland to Japan. It is indigenous throughout Asia Minor, the Caucasus and the whole of northern Asia. It occurs in every European country; but is absent from the south of Spain, Sicily and the islands of the western Mediterranean. It is generally a characteristic tree of the plains, becoming more frequent and attaining its best development towards the north and north-east. It reaches the Arctic Circle in both Europe and Asia; and, either in pure woods or mixed with birch, covers extensive tracts in Scandinavia and Russia. Towards the south it only occurs as a scattered tree in mixed woods. It ascends the mountains of central Germany to about 3,150 feet, the Riesengebirge and Baierwald to 4,000 feet, the Alps to 4,920 feet and up to 6,230 feet as a bush: and in the Pyrenees to 6,000 feet.

In the British Isles the aspen is widely distributed but is by no means a common tree, the individual occurrences being extremely scattered.

I.4. REQUIREMENTS OF LIGHT, CLIMATE AND SOIL.

(a) Light. The aspen, with its lofty, open, sparse and lightly-foliaged crown is exacting in regard to light. Among broad-leaved trees it is second only to the birch as a light-demanding species, and even in comparison with conifers is only outrivalled in this respect by the larch. The form of the crown and the arrangement of the leaves indicate the light-demanding character of the tree. On sufficiently fertile and moist soils the aspen can, however, endure a good deal of shade. It grows well on some northern aspects and in valleys as well as in mixture with strong shade casting species such as Norway spruce. However, it cannot put up with direct overhead shade and thus when once caught up in growth and somewhat over-topped by trees, which it has outstripped in growth during youth, the aspen soon sickens and dies. In Western Siberia the aspen is found as an undergrowth species to pine. The pine growth is of a very open nature and hence sufficient light reaches the aspen, which occurs along with Siberian willow and yellow acacia.

It is noticeable that the suckers are strikingly intolerant of shade in their early growth and will not succeed even under the crown of the parent aspen tree if this is large.

(b) Climate. With regard to climate the species is very accommodating and hardy. The aspen is essentially a cold and moisture-loving tree requiring a very short growing season and thriving where frosts may occur every month of the year. Nevertheless, it grows well in hot and dry regions. It is generally hardy against frost damage, principally perhaps because the leaves flush very late. Indeed the aspen is one of the latest trees to flush. Even so the flushing leaves are sometimes scorched

Photograph 15. An aspen growing in an exposed position in Scotland showing the effect of the wind on the branch formation.

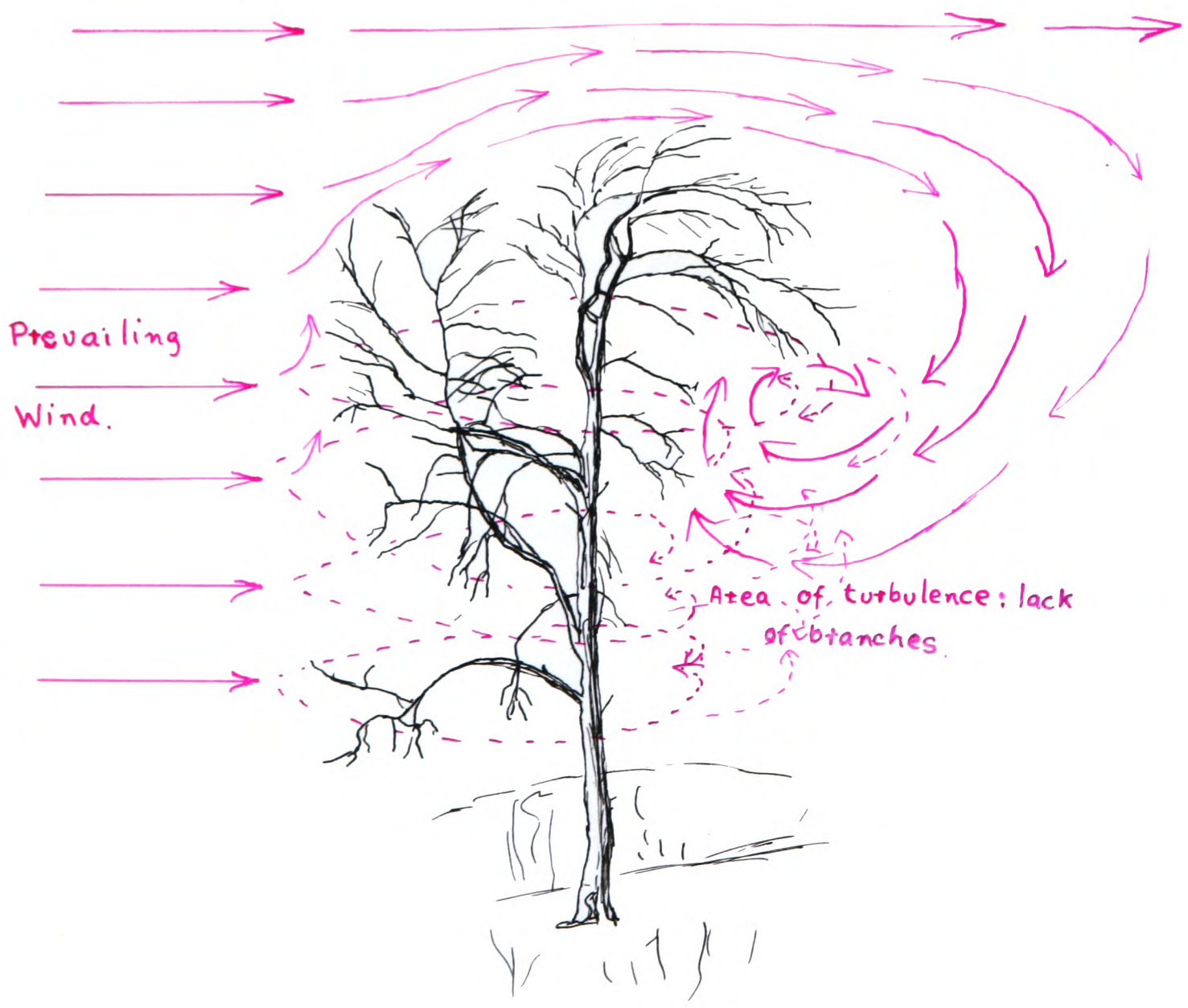


Figure 1. Diagram showing the way an area of turbulence is created on the leeward side of an exposed tree, and the consequent branch formation.

by late frosts. Also the catkins are vulnerable when the buds burst. In spite of such setbacks the tree does not suffer much, probably on account of its strong vegetative reproductive capacity. Mathiesen (26) records that in Estonia in 1940 aspen stands survived a frost of -40°c. unharmed, whilst stands of ash, oak, black alder, and hazel suffered much in open places and died after a few years.

The branches are sometimes broken by wind or ice, but seldom by snow because of their ascending nature. Lack of symmetry in the crown may, however, result in snow break. In exposed situations the healthy tree is fairly resistant to storm despite shallow rooting, but the effect of wind is shown by the branch formation, the branches being bent over in the direction of the prevailing wind and somewhat lacking on the leewardside as shown in Photograph 15. The reason for this formation is shown in Figure 1.

Old trees which have been attacked by root fungi are readily blown, particularly if suddenly exposed owing to the removal of protective trees on the windward side. It is the presence of root and wood rotting fungi, which contribute greatly to the very poor appearance and broken crowns of many of the aspen trees in Britain. (See photographs in Part II.)

In general the aspen grows best in sheltered places with a moist atmosphere, but is inexacting in respect of air temperature, and not susceptible to periodic flooding.

(c) Soil. The aspen is relatively exacting as regards soil fertility; it grows well, in the main, on fresh sandy loams, clayey and clay-loam soils and also on fresh sands rich in food material. It is unsuited for dry, stony and sandy soils and also on waterlogged soils where it dies off fairly rapidly. It makes excellent growth on the alluvial soils of river valleys and mouldy moist sites

where the mineral soil is fairly rich in lime. The best stands are found along the slopes of river valleys where there is good drainage, and also on fertile soils with moving ground water. The depth of soil seems less important provided it is not so shallow that it is readily dried out, but the best growth usually occurs on deep soil. If the aspen does grow on dry soils it is dwarfed and scrubby. The same is true on soils with high-lying stagnant ground water, indeed aspen is rarely found, if ever, on mud swamps or on Sphagnum or raised bogs, nor on wet birch peat moors. But aspen may appear in scattered places within the moors - on the higher parts where mineral soil is at the surface and where some degree of drainage occurs. For aspen moving ground water is more important than a soil,rich in nutrients, although the latter is required also for the best growth. It has been calculated in Russia (Remozov and Bykova 29.) that the nutrient requirements of aspen considerably exceed those of lime and oak. This indicates that for the best possible aspen growth, only the best forest soil types should be used.

I.5. THE ECOLOGY OF THE ASPEN

The aspen is essentially a pioneer species; it is found naturally a-s a step or seral stage, in the natural succession and not in the climax community. The tree possesses many of the characteristic features of a pioneer species: it has an abundance of seed practically every year; the seeds are extremely light in weight and are carried easily by wind or water because of the attached woolly pappus; the tree spreads exceedingly rapidly by means of root suckers which can be formed by trees of only two or three years of age; the tree grows quickly in youth and does not suffer from sunscorch; it is very light demanding; it is a relatively small tree, as a rule, and is short lived. All these characteristics help to enable the tree to colonize bare land and also largely prevent it from entering areas which are already covered by trees.

Thus the aspen, in many areas, is found as a component of the first association after clear-cutting or disasters such as fires. The aspen associations are thus temporary types into which preclimax and climax species can find entry and gradually oust the aspen. Therefore, in order to maintain the aspen, special measures must be taken to prevent ingtrusion of unwanted species. However, generation after generation of pure aspen appears undesirable and hence some degree of mixture is beneficial.

Depending on the prevailing conditions in the place concerned, the aspen, in nature, is replaced by either leaf trees or conifers. In the main aspen region in northern Europe, the species that most usually replaces it is the Norway Spruce, but further south in the broadleaved zones species such as oak or lime come in and replace the aspen.

In the initial colonization of an area after clearing or burning, the aspen is rarely the only species

concerned. Most frequently other pioneer species such as birch and rowan accompany the aspen and any one of these species may be predominant depanding on the prevailing conditions.

The position is very similar in North America with the aspen species there. Indeed they play an extremely important rôle as pioneers after fires which cause such a tremendous amount of denudation every year. According to Elwes and Henry (13) Sargent says that on account of the aspen's (P.tremuloides) remarkable power of germinating on burnt soil, and rapidly covering mountain sides which have been devastated by fire, it has had a greater influence than any other tree on the composition and distribution of the subalpine and boreal forests of North America.

In northern and central British Columbia, the forest is advancing into grassland areas, especially in the inter-mountain valleys and the plateaux between the coast Range and the Rocky Mountains. The tree which is responsible for the advance is P. tremuloides. It is often succeeded by Pinus contorta. The aspens (P. tremuloides and P. grand-identata) are replaced in due course on the best soils by leaf tree species such as Acer saccharum, Betula lutea, Fagus grandifolia, Tilia americana, and Ulmus Americana, and on very poor and dry soils by conifers such as Pinus resinosa, P. strobus, P. banksiana, Abies balsamea, and Tsuga canadensis.

Aspen and birch also come in after clear-cutting of pines etc. on the heavier soils which are suited to the growth of these leaf trees.

Both in Europe and America, the aspen plays a similar rôle in reforesting cut-over and burnt-over forest land. It also spreads from woodlands on to surrounding land. It makes its appearance on abandoned arable lands, and along ruts of neglected forest roads. It even occurs

along with such species as birch and grey alder on areas over which extensive, completely mechanized, felling and skidding operations have been carried out (Jakovlev 17). These operations usually destroy any undergrowth that there may have been and also many of the seedbearers, and thus the land is made ready for the reception of the light seeds of pioneer species.

Aspen is therefore, a true pioneer or colonizing species and as such has an important silvicultural value making way for other more valuable species by creating a soil-protecting cover, a forest environment which is so very important and it also has a beneficial effect on the soil.

However, rapid colonization, particularly by sucker growth is not everywhere desirable and quite frequently the aspen becomes a nuisance. This is particularly so on farmland or roadsides and in new plantations.

In plantations, however, the characteristics of aspen make it quite suitable as a nurse species, if the sucker growth is controlled to some extent. For nursing purposes, either natural growth by suckers or planted aspen can be used. It may be useful to allow the aspen to advance a little before introducing the other species, or both can be introduced together. It is important that the species are ecologically suitable and hence a preclimax species which commonly follows aspen in nature should be used. Thus aspen is an extremely good nurse to spruce in Europe. These two species are frequently associated together. Either may be predominant depending on the stage of evolution which has been reached. A successful example of aspen nursing spruce in a plantation is shown in Photograph 111.

As has been stated previously, the aspen is rarely found pure over large areas, but normally grows in small groups. The groups are most frequently composed of trees

Photograph 16. A typical small group of aspen suckers at the edge of scrub-woodland. Laurentian Mountains, Quebec, Canada.

of one sex only as most groups are clones which have been produced by root suckers. A typical small group is shown in Photograph 16.

In the lower areas in the northern European countries aspen is usually associated with spruce, but in the higher areas it occurs in mixture with birch. This latter association is characteristic in some areas of the Scottish Highlands where the spruce is not indigenous.

In mixture with either leaf trees or conifers the aspen has a silvicultural value in that, in general, the litter is soil improving. Exceptionally, however, according to Mathiesen (26) a raw humus may be formed. This occurs in Estonia under dense closed groups of old aspen, which may be composed of only ten to twenty stems, but each with a wide, dense crown. Under such a cover there is no vegetation as there is not sufficient light for any plant. Rare exceptions are diffused moss plants such as Hylocomium proliferum, Dicranum undulatum and Mnium spp.. The soil in such a stand is usually covered with a thick, dead layer of old aspen leaves penetrated by hyphae of various fungi, thus forming a hermetical cover. This cover has a stimulating effect on the formation of raw humus. The old aspens are evidently not detrimentally affected by this raw humus, for their roots reach out of the dead-layer area. The thick layer is an effective obstacle to the reproduction of spruce, thus favouring a new generation of aspen, which may occur after stormcasts, forest fires or clear-cuttings. A layer of aspen leaves in this area (Estonia) is thicker than in birch and alder stands under similar conditions. The causes of this are, the wide crowns; complete closure of the canopy formed by the aspen groups; and relatively heavy leaves which cannot be transported away by wind because of the stands density. In this respect old aspen stands can resemble beech stands under which raw humus is formed.

Normally, under aspen there is no complete absence of ground vegetation as the crowns are usually of a light nature. The type of vegetation naturally varies with the nature of the site and hence no generalization can be made.

The plant associations in which aspen occurs are thus extremely varied. They range from conifer forest to rich broad-leaved forest and from a lack of ground vegetation and raw humus to a lush vegetation of rich grass and herbs. It is a tree, therefore, which forms part of many associations and cannot be said to be truly characteristic of any. In its culture, its light-demanding and pioneer nature must always be allowed for, and appropriate measures taken to eliminate excessive competition or unwanted species of a later seral stage.

I.6. THE GROWTH, AND YIELD OF ASPEN

No data are available for growth and yield of aspen in Britain as the tree has been such a neglected species. Therefore, for information on these factors one must look to the literature from other countries.

Both the type and rate of growth are naturally, as in all other trees, determined by the nature of the site and the particular strain of aspen. In general, whatever the nature of these variables, the aspen tends to grow relatively rapidly in youth, but more slowly in later life. The poorer the strain and the site, the poorer is the height growth reached.

On good aspen sites, heights of 80-100 feet are possible provided the strain is a good one. Some examples of height growth (to nearest foot) in aspen stands on good sites are given in the following table.

TABLE 2. The height growth of aspen according to various sources.

Author & Country	Age in years									
	10	20	30	40	50	60	70	80	90	100
Vargas bedmar 1846, Russia			40	53	65	78		87		97
Tyurin 1925, Russia	21	36	49	61	70	78	83	88	90	92
Eklund & Wenn-mark, 1925 Sweden			50	60	69	75	80	83		
Zehngreff 1947 U.S.A.		40	51	62	70	76	82	86		
Mathiesen 1949 Estonia	22	36	49	61	71	79	86	92	96	98
Børset 1956 Norway		37	50	62	72	80	86			

It is unlikely that the sites from which the above data have been taken are strictly comparable, but the figures given are similar.

The diameter increment, more than height growth, depends on the degree of thinning. Some figures (diameter in inches) taken from aspen on good sites with a moderate thinning are given in Table 3.

TABLE 3. The diameter growth of aspen according to various sources

Author & Country	Age in years							
	20	30	40	50	60	70	80	100
Tyurin 1925, Russia	4.2	5.9	7.5	9.1	10.6		12.6	13.5
Mathiesen 1949, Estonia.	5.4	8.2	10.9	13.3	15.4	17.2	18.7	20.5
Børset 1956, Norway.	2.9	4.8	6.9	9.1	11.4	13.3		

The difference between the diameters measured in Estonia and those measured in Russia and Norway are marked. The Estonian trees show a very fine growth and it is in the Baltic States that the European aspen finds its optimum.

The aspen has a bole which has very little taper and hence the form factor is fairly high. Eklund and Wennmark (12) showed that the form factor for Swedish aspen decreases slightly with increase in age. Whilst the form class shows a tendency in the opposite direction:

TABLE 4. The form factor and form class of Swedish aspen (Eklund & Wennmark 12)

Age yrs.	25	30	35	40	45	50	55	60	65	Mean
Form factor u.b.	0.522	.517	.511	.509	.503	.499	.493	.489	.483	.503
Form class	0.643	.655	.665	.673	.679	.683	.686	.688	.690	.674

In Norway, the form factor for aspen also shows only slight variation and the relation between form factor, diameter, and height is fairly weak; Constant form factors may be used for practical purposes as no great errors are thereby involved. The arithmetic mean for the form factors investigated in Norway (Børset 5) is 0.499 which can conveniently be rounded off to 0.5. This agrees with the Swedish figure and 0.5 could be considered a reasonably accurate generally applicable form factor.

Aspen tends to be of a size intermediate between birch and spruce and the total output of aspen stands is likewise intermediate between birch and spruce stands on the same sites.

According to various authors the volume and total production on the best aspen sites are as follows: -

TABLE 6. A yield table for heavily thinned aspen stands of the experimental forest of Peravalla, Estonia. (after Mathiesen 26)

Age yrs	per acre: STANDING TREES: No.of trees	Mean ht. ft.	Mean diam ins.	Basal area sq.ft.	Vol. cu.ft.	FELLED TREES: No.of trees	Vol. cu.ft.	Total production cu.ft.	Current annual increment cu.ft.	Mean annual total increment cu.ft.
10	1215	21.6	2.5	43.2	715			715		72
						466	57		97	
15	749	28.9	3.9	58.7	1144			1201		79
						263	57		97	
20	486	36.1	5.4	78.6	1573			1687		84
						97	157		117	
25	389	42.6	6.8	99.3	2002			2273		92
						88	186		137	
30	301	48.9	8.2	111.1	2359			2816		99
						72	243		166	
35	229	55.1	9.6	116.3	3089			3789		109
						34	386		172	
40	195	60.7	10.9	127.6	3560			4303		116
						30	400		175	
45	165	65.9	12.2	134.6	4032			5275		123
						21	443		177	
50	144	70.5	13.4	141.1	4475			6161		129
						17	486		200	
55	127	75.1	14.4	144.2	4919			7091		133
						13	472		172	
60	114	79.1	15.4	149.4	5306			7950		136
						10	458		166	
65	104	82.7	16.3	153.3	5676			8778		139
						8	458		157	
70	96	85.9	17.2	157.3	6005			9565		140
						6	458		155	
75	90	88.9	18.0	159.9	6320			10338		142
						5	443		152	
80	85	91.8	18.7	163.3	6634			11095		142
						4	372		114	
85	81	94.1	19.3	166.0	6892			11725		140
						3	243		89	
90	78	95.8	19.8	167.3	7092			12168		137
						2	257		77	
95	76	97.1	20.2	168.6	7221			12554		134
						1.6	174		72	
100	75	98.4	20.5	170.3	7364			12871		132

TABLE 5. The volume and total production of aspen according to various sources.

Author & Country	Vol./acre in cu.ft.			Total production/ acre in cu.ft.		
	30 yrs	50	80	30 yrs	50	80 yrs.
Vargas de Bedemar 1846 Russia	3200	5360	7700			
Tyurin 1925 Russia	2660	4560	6690	3700	6530	9580
Eklund & Wennmark 1925 Sweden	2390	3490				
Petrini 1944 Sweden	1790	3150		2000	5050	
Mathiesen 1949 Estonia	2360	4470	6630	2960	6400	11280
Børset 1956 Norway	1630	2970		2130	5130	

It can be seen from the above, that volume production is quite variable and no general figures can be obtained, but it is clear that reasonable volumes can be obtained in a rotation of 60 or 70 years on the best sites. More detailed data on the growth of aspen in Norway where the aspen grows well but does not reach such large dimensions, as in Estonia and the surrounding areas, is given in Part III. Also comparisons of aspen and spruce growth in Norway are given.

In order to illustrate the possibilities of well managed aspen in its optimum area, a yield table for heavily thinned aspen stands on the best soils in the Experimental forest of Peravalla in Estonia (Mathiesen 26) is given in Table 6. This table has been converted from the metric system to the British system.

From the foregoing information gathered from several sources throughout the aspen's range, it is clear that the growing of aspen with proper treatment is sound, as very reasonable quantities of timber can be produced on sites that suit it. On poorer sites, aspen naturally does not grow as well and it is doubtful whether such growth would prove profitable. With aspen, the question of rot must always be considered as this factor results in a considerable loss in volume. But in vigorous stands, properly handled, increment may exceed rot development and so the trees yield considerable amounts of merchantable timber.

I.7. AN ACCOUNT OF OTHER SPECIES OF POPLAR AND HYBRIDS

The genus Populus contains many species indigenous in localities around the Northern Hemisphere. Table 1. shows the six different sections of the genus and the geographical distribution of the principal component species.

The sections Leucoides and Turanga are of little importance in Europe and therefore the four remaining sections only, will be dealt with.

The general characters of the main sections of the genus are described in the following table: - (Peace 27)

TABLE 7. The general characteristics of the main Populus sections.

Section	Leaves	Leaf stalks	Buds
LEUCE (White Poplars)	Dense white hairs on under-side of leaves on rapidly growing shoots	Roundish	Dense white hairs on buds
TREMULAE (Aspens)	Roundish without translucent margins.	Strongly flattened	Dryish
TACAMAHACA (Balsam Poplars)	Without trans-lucent margins	Roundish	Sticky with strong balsamic odour
AIGEIROS (Black Poplars)	With trans-lucent margins	Flattened	Less sticky and with less odour

(A). Section Leuce, The White Poplars

In this section there are two species: Populus alba, the White Poplar or Abele and P. canescens, the Grey Poplar. The former is an introduction to Britain of long standing, but the latter is considered to be indigenous to Central

Photograph 17. Large grey poplar trees. Kingussie, Inverness-shire.

Photograph 18. Large grey poplar trees. Kingussie, Inverness-shire.

and Southern England. It has been suggested that the grey poplar, because of its many, seemingly, intermediate characteristics, is a hybrid between the white poplar and the aspen. There is, however, no proof of this and indeed, as the grey poplar is indigenous and the white not, it is difficult to see how such a hybrid could have been formed.

The white poplar grows into a small tree, usually not more than fifty feet high. It has attractive maple-like leaves, covered in white hairs which remain on the leaves until the autumn. The tree, therefore, has silvery foliage which is readily moved by the wind. The wood of this tree is softer and more spongy than that of other poplars and hence the tree has little value but for its aesthetic appeal. It is, however, a good tree for seaside planting, being resistant to salt winds. Its habit of suckering detracts somewhat from its value as an ornamental tree. The tree is often attacked by dieback, the cause of which has not been ascertained.

The grey poplar is a faster growing tree than the white poplar and often reaches a very large size, as can be seen from Photographs 17 and 18 which are of trees in Inverness-shire. These trees are between 85 and 95 feet tall, and the largest has a quarter girth at breast height of 30¾ inches. A tree on Loch Ness-side has a quarter girth at breat height of 41 inches.

The grey poplar as instanced by the above, is able to grow well in the cooler parts of Britain, but does not grow at such an altitude as the aspen.

The leaves of the short shoots are shaped like those of the white poplar but are broader. The leaves of the long shoots are coarsely sinuate-dentate and not palmately lobed. Their undersides are either coated with grey down or are smooth, but always there is a tuft of

Photograph 19. Three or four-year old root suckers of grey poplar at the time of leaf-flush. Old Scone, Perthshire.

hairs at the base near the petiole. The leaves are thickish.

The tree grows on a variety of soils but requires at least a moderate fertility. The tree, and its growth appear rather variable and any propagation should be carried out with material from trees of good form only.

Both the white and the grey poplar sucker freely, but not to quite the extent that aspen does. Suckers of grey poplar at Old Scone, Perthshire are shown just after leaf flush in Photograph 19.

(B). Section Tacamahaca, The Balsam Poplars.

The balsam poplars are a group characterized by their odour, which is particularly strong when the catkins or leaves flush. These poplars in contrast to the aspen are generally propagated from cuttings but like aspen and the white poplars sucker freely. This factor detracts from their value as ornamentals although many are grown as such. Unlike the aspen, the balsam poplars frequently show epicormic branching which detracts from their value as timber trees. Most of the species of interest in Britain are natives of America.

Populus trichocarpa is the finest timber-producing poplar in America; though the timber is inferior in quality to that of the Black Poplars. As long as the tree remains free from bacterial canker, which is the most damaging disease of poplars in Europe, it grows well in all parts of Britain, especially in the higher rainfall areas. In parts of Scotland it does very well and it might be a suitable species for the mountain regions were it not for its extreme susceptibility to bacterial canker. A large number of hybrids between this species and others are being tested in the hope of finding a bacterial canker-resistant variety.

P. tacamahaca or P. balsamifera grows as far north as Alaska in North America. Several trees of this species occur in Britain, mostly as roadside trees in Scotland. They are rather small bushy trees with poor timber. They appear, however, not to be attacked by bacterial canker, and hence may prove of value in crossings.

P. candicans (recently renamed X. P. gileadensis Roul)

The Balm of Gilead poplar, is a tree of obscure origin, possibly a hybrid. In Britain it has been planted primarily as an ornamental tree. It is susceptible to bacterial canker and few large trees are found, except in the Highlands of Scotland.

(C). Section Aigeiros, The Black Poplars.

The black poplars appear to be so called, not by reason of any blackness of leaf or bark, but because of the absence of any white or grey down on the underside of their leaves. Nearly all are very easily rooted from cuttings, though a few are, for unexplained reasons, harder to deal with. They do not sucker nearly as freely as the poplars of the other sections, but suckers do arise from the roots of recently felled trees.

The black poplars are nearly all very fine timber producers and in consequence have been more widely used in plantations than have members of the other sections. Very many hybrids have been formed.

P. nigra, the European Black poplar, is divided into a number of varieties, the main ones being P.nigra var betulifolia Torr., P.nigra var typica Schn., and P. nigra var italica DuRoi. The former is native of Britain and western Europe and is distinguished by its hairy branchlets from the glabrous var.typica which is native of southern Europe and western Asia. Both varieties

have short trunks and wide spreading crowns, and are distinguished from other poplars by the large burrs which occur on the trunks. They often reach a very large size but are not particularly rapid in growth and this coupled with their short trunks and heavy crowns renders them of little value for timber production.

The variety italica is the well known fastigiate Lombardy poplar which probably originated as "sports" from the normal varieties. Because of the low heavy branching the tree is of no value as a timber producer.

P. deltoides, the American Black Poplar covers an enormous range in the United States and southern Canada. It has been introduced successfully into Europe, particularly into France, where it has not only served as parent to some of the most valuable older hybrids, but has also been widely planted for timber production. In Britain the tree is seldom met with outside arboreta.

A very large number of hybrids have been formed within the Black poplars, the principal ones are:-

X P. serotina, the tree usually planted in Britain under the name "Black Italian poplar" is almost certainly a hybrid between some form of P. nigra and some form of P. deltoides, but it existed before 1755 and hence its origin is conjectural. It has a long stem and heavy slightly upcurved branches; it is a male tree. Several trees have been recorded in which the combined volume of trunk and major branches exceeds 1,000 Hoppus feet and hence it is a fine timber producer. The tree is resistant to bacterial canker, is late-flushing and consequently hardy and is a good tree for poplar plantations. A number of varieties have been named but are not really of importance.

X. P. regenerata is a female tree, closely resembling X. P. serotina in its foliage but has more

steeply angled branches. It is thought to have originated as a cross betwen P. nigra and X.P. serotina. Some varieties are susceptible to bacterial canker and some not.

X. P. eugenei is a male tree arising from X. P. regenerata and P. nigra var italica. It has a narrower crown than X. P. serotina and grows rapidly. It grows quite well on rather dry sites. Once again one variety appears susceptible to bacterial canker, and the other not. Once these are definitely sorted out, the resistant variety will probably be a valuable fast growing hybrid in Britain.

X. P. robusta is likewise a male tree. It is considered to have arisen from P. deltoides var angulata and P. nigra var plantierensis. X. P. robusta is a very rapid growing tree of extreme straightness, with moderate sized, fairly steeply-angled branches. It is not outstanding in the nursery, but after planting it is superior to most other poplars, up to the age of 25 years when its growth rate falls slightly. In Belgium it has been used on a large scale for match manufacture and to some extent in Sweden. It has doubtful resistance to bacterial canker.

X. P. gelrica is a hybrid between X. P. serotina and X. P. marilandica. It is another fast growing hybrid reaching a comparable height to X. P. robusta but it has a greater girth increment and hence a greater volume production. It is rather poor where straightness is concerned, but nevertheless, it is worthy of planting, particularly as it is resistant to bacterial canker.

The black poplars and their hybrids and, to some extent, the balsam poplars and hybrids between these and black poplars or their hybrids, assume the most important rôle in poplar cultivation in Western Europe and Britain.

This is primarily due to three reasons: - (a) the ease in propagation by means of cuttings, (b) the extremely rapid growth and hence a high volume yield in a very short period of time (25-30 yrs.) and (c) the straightness of stem and general good form.

In recent years the fast growing poplar species and hybrids have tended to eclipse such species as the aspen, for which rather special artificial regeneration operations have to be carried out, and which is extremely prone to damage by rot (though not particularly so by bacterial canker). If treated properly, natural regeneration of aspen can be utilized to good effect and produce valuable timber. The cultivation of the faster growing poplars is, however, rather different and almost approaches a form of tree farming. This is because the plantings are carried out at such wide espacements that little forest environment is created and the trees remain more as individuals instead of forming a wood. Artificial high pruning must, as a rule, be resorted to and hence poplar cultivation must be considered rather apart from normal forestry which aims to utilize nature as much as possible, working on a long term basis and not wholly on a short term, quick financial return basis with little thought for posterity. The methods generally employed in the cultivation of fast growing poplars are as follows: -

A forest nursery which is to be used for poplars must have a reasonably deep and easily worked soil. The poplars are heavy feeders and respond to manuring, farmyard manure or compost being preferable. Acidity should be counteracted by the use of lime.

Poplars may be raised from stem-cuttings, root-cuttings, layers, seed or sets, but normally stem-cuttings are used.

The cuttings should be eight or nine inches long and $\frac{3}{8}$ inch in diameter, and taken from well ripened one-year old wood. The cuttings should be inserted vertically in well cultivated soil, the top being flush with the soil surface. Spacings of nine inches within, and eighteen inches between, the rows are usual. The shoots which arise from the cuttings are reduced to one, and in the first year a growth of about eight feet can be expected. The plant is then stumped back to within an inch of the root collar and the next year's growth treated as the first. In the second year, usually after transplanting at the time of stumping, a growth of between six and eight feet is obtained. At the end of the second year the plants are ready for planting out.

Before planting, it is necessary to reduce the branches, thereby reducing transpiration and the risk of dieback during the first season in the field.

The Forestry Commission (27) recommend that a spacing of not less than 18 ft. by 18 ft. and not more than 24 ft. by 24 ft. should be used in planting. It is hoped that by the use of this wide spacing no thinnings will be required before maturity.

The planting must be carried out in pits and the plants well firmed in. For a year or two after planting it is necessary to make sure that the trees are not shaken about by the wind. Pruning is necessary throughout the life of the tree and this should be done so that about half the total height of the tree is completely free of branches.

The poplars should only be grown on good sites in sheltered positions. The water table should never be less than two or three feet below the surface and never more than four or five.

It is clear that the volume production per acre of poplar can never be high, owing to the wide spacing required. Productiveness is dependent mainly on the short rotation, which, in theory, enables two or three crops of poplar to be harvested from one piece of ground in the same time as is required for one rotation of a coniferous crop. It is thought that the desirable rotation will vary according to site quality between 24 and 30 years in southern England and between 30 and 36 years further north.

On a very good site, final crop yields of about 4,000 Hoppus feet per acre, over bark, can be expected. Several typical examples of growth from Great Britain are shown in the following table:- (Peace 27)

TABLE 8. Volume Production of Poplar in Britain

Place	Species	Age yrs.	Ht. ft.	No. of trees /acre	Vol/ acre H.ft.	Vol/ tree H.ft.	Remarks.
Ryston Norfolk	X P.robusta	23	.	237	2,750	11.6	Under thinned.
Ryston Norfolk	X P.robusta	24		74	2,500	33.8	
Dawyck Peebles	P.trichocarpa	25	55	540	2,395	4.4	Under thinned
Rendlesham. Suffolk.	X.P.serotina (some X.P. eugenei)	28	80	56	1,066	19.0	Too dry a site. X.P eugenei cankered.
Brahan Castle Ross-shire	X.P.regenerata.	? 30-35	85	100	4,150	41	
Ladywood Raby Castle Durham	X.P.serotina	? 35	64	280	2,080	7.4	Mixed with Norway spruce

Hybrid black poplar growth is far superior to that of aspen. The length of time that aspen takes to reach a large size is very considerable in comparison with the black poplars. Nevertheless aspen should retain its position among the utilizable poplars because of its timer value.

(D) Aspen Hybrids and Triploids.

In Denmark, Sweden and Finland so called giant or triploid aspen have been found. In all cases the triploid aspen shows a greater rate of growth. In Denmark a triploid aspen at 56 - 57 years of age was found to be 11% taller, 10% larger in diameter and with a volume 36% greater than diploid aspen in the same area. It has also been shown that the growth of triploid plants is greatly superior (Larsen 23).

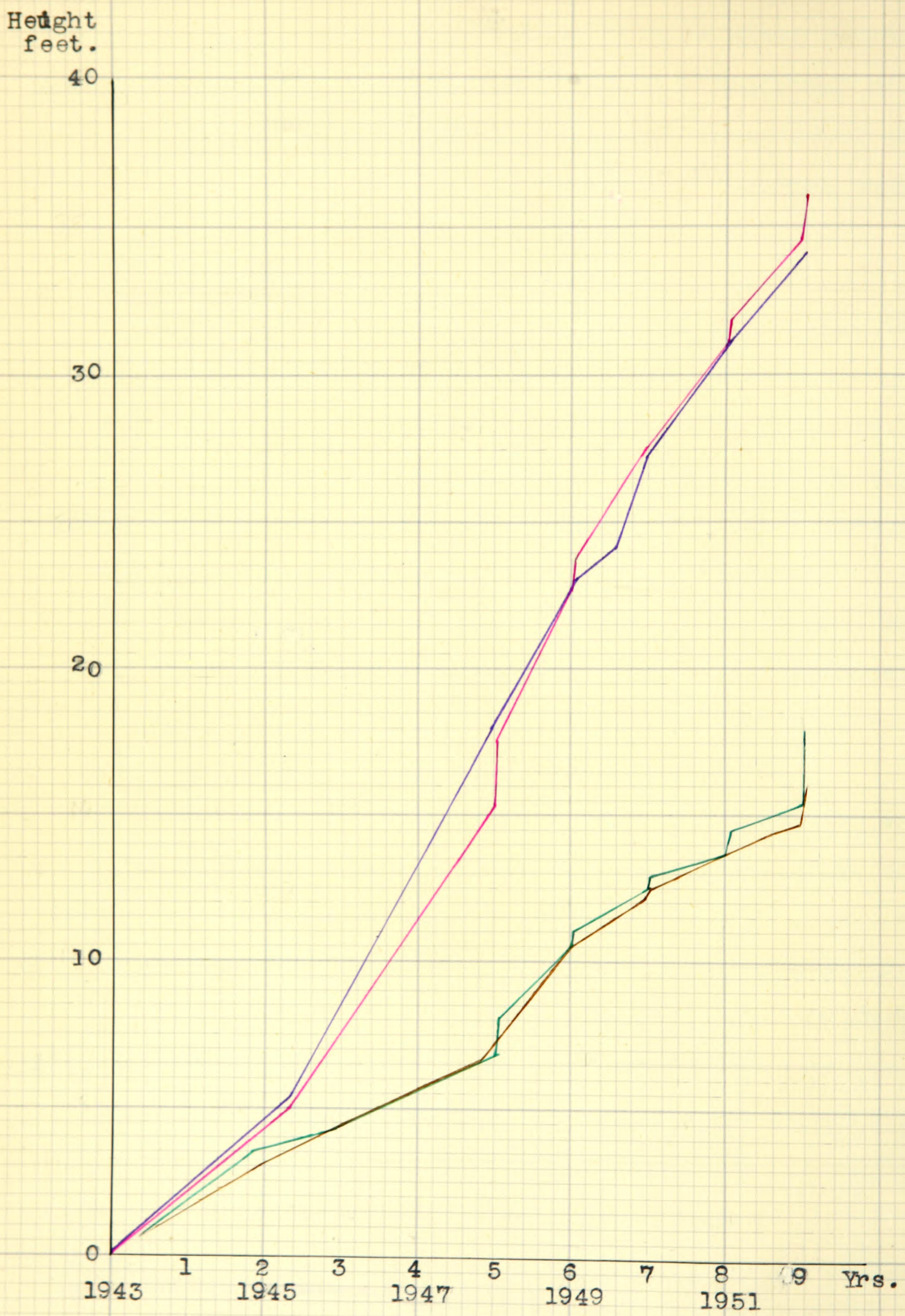
The hybrid aspen P. tremula X.P. tremuloides has been found to show a greater growth rate than even the triploid plants. Whilst it also shows greater resistance to attack by rust fungi. Of course the individual hybrids show varying growth and it remains to be seen which different crossings prove to be of most value to the different countries. So far, in Denmark the hybrid between P. tremula from Poland and P. tremuloides from around Vancouver, B.C. appears most promising (Larsen 23).

It must be realised, however, that so far, the most advanced trials are only about ten years of age and no definite conclusions can be drawn.

In Sweden, using a cross between Swedish and Canadian aspen, the hybrid at six years of age has reached 13.8 feet in height, has a stem volume representing 215 cu.ft. per acre and a current annual increment for the last year of 57 cu.ft. per acre. The corresponding

FIGURE 2

GRAPHS SHOWING THE DIFFERENCES IN HEIGHT GROWTH BETWEEN HYBRID ASPEN AND NATIVE ASPEN IN SWEDEN (19)



figures for Swedish aspen in the same area are 6.9 - 10.8 feet in height, a stem volume of 33 - 70 c.ft. per acre and a current annual increment of 10-11 cu.ft. per acre.

Figures from America also show an increased initial growth rate of the hybrid over pure native P. tremuloides: - (32)

TABLE 9. Comparison of the initial growth of hybrid and native aspen in America.

Description	Survival %		Average Ht.%		Height of tallest tree, fourth year.
	Third year	Fourth year	Third year	Fourth year	
P. tremuloides of Mass. X. P. tremula of Germany	88	82	4.8	6.1	11.0
P. tremuloides Native	74	56	3.3	5.2	9.3

The hybrid, however, shows poorer form in this instance than the native P. tremuloides.

Curves produced in Sweden by H. Johnsson (19) show the relative growth rates of hybrid aspen and P. tremula and for diploid and triploid varieties. The experiment is eight years old and as can be clearly seen from the curves in Figure 2, the hybrid aspen shows a growth of almost double that of the pure species. The difference in both cases between diploid (2x = 38) and triploid (3x = 57) plants is not so definite although the latter at eight years are larger in both cases. The very considerable superiority in favour of the species crossing, far outweighs the question of whether the plants are diploid or triploid.

The increased growth rate of the hybrid between the two species over both the pure species may be caused by one of two reasons, or a mixture of both. Firstly, it

may be due to heterosis causing what is commonly termed hybrid vigour, and secondly it may be due to photo-periodism. As has already been stated, P. tremula of more southern latitudes produce more if they are taken north. Now in each of the species crossings in Europe, the father has come from a more southern latitude than the mother and vice versa in the American crossings. Thus there is a change of photoperiodism from south to north in each case and this may account for the better initial growth.

A great deal more work on this question of the value of the hybrid between the species is required before any definite conclusions can be drawn and, if necessary, actions taken.

I.8. DISEASES, PESTS, AND OTHER CAUSES OF DAMAGE.

Aspen is extremely susceptible to damage caused by various means. Most frequently one form of damage leads to another and hence most of the fungal diseases occurring in aspen find their initial entry through wounds caused by other agencies. It is essential that when considering the different diseases to which aspen is prone, each type of disease is taken separately. There are four major categories of damage that must be considered. These are (A). Damage caused by inorganic agencies. (B). Damage caused by mammals. (C). Damage caused by insects, and (D). Damage caused by fungi and bacteria.

A. Damage Caused by Inorganic Agencies.

(a) Wind. Aspen is capable of growth in extremely exposed situations and in Scotland is frequently found in such positions as is shown in Photograph 15. However, the tree flourishes most in extremely sheltered places, where the effect of the wind is seldom felt. When aspen is exposed to the wind the tree often leans away from the direction of the prevailing wind and thus the stem is bent. Also in common with a number of other species the effect of the exposure is readily visible in the form of the crown. Many branches are broken and the crown is very unhealthy. This is especially the case in older trees. Occasionally aspen stems are broken by the wind, but this is exceptional in healthy trees. The constant rocking of the tree in the wind contributes to a great deal of damage. As the tree rocks to and fro the roots are damaged to some extent; in severe cases the narrow roots may be completely broken, but more normally only the rootlets are broken or the root-bark

slowly worn away by the constant friction. This type of damage is the primary cause of fungal attack and rot in the roots of medium and large sized aspen. Such root breakage and rot make the tree extremely vulnerable to wind blow.

(b) Frost. Aspen is a frost hardy species being able to withstand intense cold. However, at the time of the leaf flush the leaves sometimes become scorched by frost, but this is a rare occurrence, since the aspen is one of the latest species to flush. The catkin buds are also liable to be damaged by frost at the time of their opening. This occurred to a marked extent in northern Britain in 1957. Frost crack occurs very occasionally and is caused by unequal expansion of the wood on freezing. The cracks extend deep into the wood and hence the timber is spoilt for veneering purposes. During the summer the efforts of the tree to heal the wound result in a raised ridge of bark above, the crack, and it is at this stage that frost crack is most readily detected. In general, damage due to frost is rare in aspen and of little consequence, being only serious on weak plants, the growth of which may be seriously retarded.

(c) Sun scorch. Sun scorch of the bark of young aspen may occur when the trees are suddenly exposed to full sunlight by the felling of a tree stand, which had previously sheltered them from the south. Such damage is not likely to be of frequent occurrence, and aspen always grown in full sunlight are quite safe from it.

(d). Drought and Floods. Aspen suffers a slight setback during periods of drought when growth is considerably weakened. This is most marked in seedlings.

In a year with a dry, hot summer, seedlings in their first year only grow to about half or two thirds of the size that they would grow in a more normal year. Lack of water can cause crown dieback in older aspen trees. This normally occurs when competition for water becomes too great. Such competition may occur from a stand of another species growing under the aspen or in close proximity to it. The aspen requires a moderate supply of water but the effect of too much water in the soil can be detrimental. Aspen can stand considerable periods of flooding, especially when dormant, but it is important that the flood water should finally flow off.

Slow disappearance by evaporation and seepage into the soil, which very nearly amounts to stagnation, will almost certainly result in dieback. This is because the roots of the trees will suffer from lack of oxygen in the stagnant water. Thus a perpetually high water table is unsuitable for aspen and the water supply for aspen should be a moving one.

(e). Soil Nutrients. As has already been stated, aspen is rather demanding as regards soil nutrients and its reaction to soils poor in nutrients might almost be regarded as coming under the heading of disease. Chlorosis, a state which is generally considered to be a symptom often associated with the lack of one or more minerals, is fairly common. Although the actual requirements of aspen for minerals is not known, it is clear that the requirements are not always met. The tree, in consequence, appears sickly. Correct siting of the species will, generally, obviate this sickliness.

(f). Miscellaneous Causes of Damage. Aspen, in common with other poplars, is regarded as resistant to smoke and fumes and therefore they can be utilized near towns. Damage is frequently caused by wire fencing and other obstacles which are placed near to or against, or fixed to aspen. The relatively fast growth and quite rapid occlusion of wounds often causes strands of wire to become embedded in the tree. Such damage renders the timber unsuitable for many uses and also serves as a means of entry for wood-rotting fungi.

A considerable amount of damage occurs in countries where aspen is treated as economically valuable, owing to extraction workings. The soft bark is readily split and removed in large patches from branches and boles when falling trees scrape against the remaining trees. Such damage, after a time, appears similar to a bacterial canker. It is important to recognize the difference. The mechanical wounding provides an easy entry for wood-rotting fungi and insects. Great care must be exercised in felling and extraction so as to avoid splits and cuts in the actual timber being taken out, as well as in that to be left standing.

B. Damage Caused by Mammals.

(a). Domestic animals. The foliage and young green shoots of aspen are readily eaten by most herbivorous mammals. In consequence aspen suffers considerably from damage by mammals. Since aspen, particularly in Britain, is found in odd corners, and the edges of woodland and mostly near farmland there is considerable danger from domestic stock. Cattle, sheep and goats cause a great deal of damage.

Photograph 20. Damage to a young aspen tree caused by deer. Nethybridge, Inverness-shire.

(b). Wild animals. Among the wild animals the rabbit, hare, deer, mice and voles are most troublesome in Britain, but in other countries many other animals such as elk and beaver must be added to this list. Most of these animals cause damage to young aspen of both seedling and sucker origin. The larger animals, the deer, the hares and rabbits frequently remove the tops of the young plants, often leaving an almost clean cut where the stem has been bitten through. The smaller animals, the mice and voles as well as the hares and the rabbits, gnaw the bark of young stems and often completely girdle them. This naturally results in the death of the plant. Girdling of the stems by mice and voles occurs most frequently beneath a covering of snow.

Larger trees are sometimes damaged by gnawing in a similar fashion by deer, but the stem is seldom completely girdled. The field vole causes damage to aspen by eating the roots below the soil surface.

Damage from mammals is normally not severe enough to prevent growth completely, but stems are frequently badly damaged. Since preference is shown by the animals for relatively small trees, the ultimate effects of the damage is confined to the inner wood. Once the wound has healed the outer wood forms normally. An example of the type of damage caused by bark stripping is shown in Photograph 20. A serious result of attacks by mammals is the means of entry provided for fungi.

C. Damage Caused by Insects.

In dealing with the damage caused by insects, a general description of the types of damage and their causes will be given. A more detailed description of the major injurious species is given in Appendix X.

Most, if not all, the insects which cause damage to aspen, also attack other poplars and sometimes the willows. Although preferences for certain species must obviously exist, it is difficult to enumerate these as sufficient information is lacking. Therefore, this section, except in certain instances, applies to the Genus Populus.

Very large numbers of insects may occasionally be found feeding on aspen; the majority of these are omnivorous species normally associated with other broad-leaved trees and shrubs. Only those species which are known to attack the aspen habitually, will be dealt with.

In the main, three types of damage may be distinguished: -

(a) The damage caused by insects with wood-boring larvae.

(b) The damage caused by bark and cambium-eating insects.

(c) The damage caused by leaf-eating insects.

Of these the first type is considered most harmful economically, but from time to time, some of the insects which destroy foliage or bark may develop to pest proportions and cause considerable damage.

(a). The damage caused by insects with wood-boring larvae.

There are three species of beetles and three species of moth which have poplar-wood-boring larvae. Of these, the Large and Small Poplar Longhorn Beetles, the Hornet Clearwing Moth and the Goat Moth are the most important.

The Large Poplar Longhorn Beetle, Saperda carcharias L. is the most destructive insect pest of poplars. Its occurrence is, however, local but it is widely distributed. The larvae feed for a time just

inside the bark where they construct chambers in the surface of the wood. They then excavate vertical tunnels in the timber; these are generally over a foot in length. The larval development may take up to two years, at the end of which the larvae pupate in the tunnels. The frequent use of the hole in the bark for the ejection of frass, prevents occlusion and in consequence sap exudation takes place. In some instances the sap becomes infested by larvae of a species of Dipterous fly and these cause fermentation of the sap and further delay in occlusion; sometimes resulting in the development of a canker.

The Small Poplar Longhorn Beetle, Saperda populnea L, is numerous in the south of England where it primarily attacks aspen. As a rule the attack is concentrated on small trees. In the first season the larva burrows a semi-circular tunnel between the bark and the wood, and a gall-like swelling develops around the point of attack. Later the larva bores into the wood where, in the centre of the stem, a two inch long tunnel is made. In some cases several small galls may be formed on the same branch or stem and subsequent breakage may result.

The Hornet Clearwing Moth, Sesia apiformis C L. is numerous in many localities and causes extensive damage at the base of the stem by burrowing into the wood. In severe attacks fairly large trees may succumb as a result.

The Goat Moth, Cossus cossus L., is widely distributed, but is more numerous in the south of England. The larvae burrow oval shaped tunnels into the wood in their second season, after overwintering under the bark. From these tunnels, several holes to the surface are made in order to enable the ejection of frass to take place. In heavily infested trees large numbers of larvae

may be present and the damage caused considerable.

The Osier or Willow Weevil, Cryptorrhynchus lapathi L., and the Leopard Moth, Zeuzera pyrina L., also burrow into the wood.

Damage of the above nature considerably decreases the value of the timber and makes it unsuitable for certain purposes. Also the damage allows easy entry for injurious fungi.

(b). The damage caused by bark- and cambium-eating insects.

The wood-boring insects, dealt with above, naturally damage the bark and cambium of the trees they attack.

The most important insect causing damage to the cambium is the Poplar Cambium Borer, Agromyza carbonaria Zett., This insect is widely distributed and numerous in many localities. The larvae bore in the cambium of the stem and give rise to pith flecks in the wood. These constitute lines of weakness, and render the material unsuitable for the manufacture of matches or veneer.

Other bark or cambium destroying species are the Poplar Bark Beetle, Cryphalus binodulus Ratz., the Short Snouted Weevils, Barypeithes pellucidus Boh., and B. araneiformis Schr., and the aphids: Pterochlorus saligna Gmelin., and Melanoxantherium salicis L., These latter form colonies on the young bark of poplars and suck the sap. They are probably associated with the occurrence of bacterial and fungoid diseases of the branches of poplars and willows.

(c). The damage caused by leaf-eating insects.

Poplar leaf-eating insects are extremely numerous and only those causing extensive damage will be dealt with.

Photograph 21. A red poplar-leaf beetle, Melasoma populi, feeding on young aspen leaves. Three leaves have been destroyed. Ås, Norway.

Photographs 22 and 23. The damage caused to aspen leaves by the poplar-leaf minor, Phylocnista labyrinthina. Ås Norway.

The Red Poplar-leaf Beetle, Melasoma populi L., is a fairly large beetle of about half an inch in length. Both the larvae and the adults feed on poplar leaves, the former skeletonize them and the latter eat out irregular holes. In some places two generations occur in one year. This beetle is shown on an aspen twig in Photograph 21.

The Blue Poplar-leaf Beetles, Phyllodecta Spp. are small, bright beetles having a metallic lustre. They cause damage in both adult and larval stages by skeletonizing the leaves, and the beetles cause further damage by gnawing the tender young shoots.

The larvae of the Puss Moth, Cerura vinula L., the Poplar Hawk Moth, Smerinthus populi L., and the Eyed Hawk Moth, S. occellatus L., all cause considerable defoliation where they occur.

The White Satin Moth, Leucoma salicis L., can be regarded as one of the worst pests of poplars, since, where the larvae are numerous complete defoliation is caused over wide areas. Fortunately, in recent years in Britain attacks have been few.

The Poplar Sawfly, Cladius viminalis Fall., and the Birch Sawfly, Croesus septentrionalis L., both skeletonize poplar leaves.

There are several species of Poplar Leaf Aphids, the commonest being Chaitophorus populi L., and Chaitophorus leucomelus Koch.,

A Poplar Leaf Minor, Phylocnista labyrinthina causes considerable discolouration of aspen leaves. Where attacks are bad, the trees become almost white. This is due to air entering the leaves as the larvae eat out zig-zag galleries just below the epidermis on either side of the leaves. No damage is done to the chlorophyll and apparently, even in bad infestations, there

Photograph 24. Gall damage on the leaf stalks of aspen caused by the poplar gall-midge, Diplosis tremulae.

Photograph 25. Galls on the midrib and main veins of an aspen leaf.

Photograph 26. Large galls on the twigs of aspen. Grantown-on-Spey.

is little effect on growth. But in the nursery, when all the leaves become white, the shoots die. Damage caused by this insect is shown in Photographs 22 and 23.

Other damage is done by insects which cause the formation of galls. These occur chiefly on the leaf stalks, but sometimes on the midribs and major side veins of the leaves. Gall damage is shown in Photographs 24, 25, and 26. Gall-forming insects are the Poplar Gall-midges, Diplosis tremulae Wtg., being the commonest on the aspen, and several aphids; - The Gall-forming Aphid Pemphigus bursarius L., the Spiral-gall Aphid, P. spirotheca Passerini, and the Leaf-gall Aphid, P. affinis Kalt.

Some leaf rolling caterpillars attack the aspen and damage of this nature is shown in Photographs 27 and 28.

In the catkins, the larvae of Epiblema nicella eat out canals in the pedicels and enter the capsules and eat out the seeds. To prevent this damage in controlled pollination, spraying a few days after pollination is effective.

Whilst not an insect, the common ant may be mentioned here. In Russia (Tkachenko 34) Formica rufa has become a notable destroyer of aspen seed. There have been cases of the complete annihilation, by ants, of aspen seed sown in nursery beds. This could account, to some extent, for the lack of natural regeneration of aspen by seed.

In most cases, many different forms of damage may be found on the same trees and when this occurs there is a marked loss of vigour, and maybe dieback and death follow. Photograph 29 shows the first stages of dieback in aspen in Norway.

Photograph 27. Aspen leaves rolled by a leaf-rolling caterpillar.

Photograph 28. A rolled aspen leaf unrolled to reveal the caterpillar inside.

Photograph 29. The first stages of dieback in aspen. Stange, Norway.

D. Damage Caused by Fungi and Bacteria.

The aspen is attacked by a number of species of fungi and bacteria and considerable damage is done by these means.

The fungal species cause damage on (a) the leaves, catkins and young succulent shoots, (b) the twigs, branches and stem, and (c) the wood of the stem and the root. Little is known concerning the bacterial diseases; bacterial canker is the main disease and this will be dealt with after the fungal diseases.

(a) Fungal diseases of the leaves, catkins and young succulent shoots.

The most important diseases of the leaves and young succulent shotts are those caused by the rust fungi of the genus Melampsora. When this fungal Genus is present both surfaces of the leaves become thickly covered with small, bright orange-yellow or brown fructifications which appear from mid-summer onwards. After a time the infected leaves wither and fall, so that a heavy attack leads to premature defoliation and consequent reduction in growth. This premature defoliation seems to prevent the proper ripening of the attacked shoots, which are subsequently damaged by autumn frosts.

There are very many species of Melampsora which attack the aspen and it is very difficult to distinguish between them. This is made more difficult as each species has a primary and a secondary host. However, three species have been named, these are: -

Photograph 30. Damage caused to aspen leaves by a species of Melampsora. Vollebekk, Norway.

Photograph 31. Damage caused to aspen leaves by a species of Melampsora. Ås, Norway.

Species	Alternate host	Poplar host
Melampsora pinitorqua Rostr.	Scots pine	Aspen & White poplars.
Melampsora Larici-tremulae Kleb.	European larch	Aspen & White poplars
Melampsora rostrupii Wagner	Dog's mercury Mercurialis perennis	Aspen & White poplars

Of these Melampsora pinitorqua is of the greatest importance, not primarily because of its damage to aspen but because of the damage it causes on the alternate host, the Scots pine Pinus sylvestris L. The disease is known as the Pine Twist. Pine trees of nursery age are mostly infected and the damage causes the young pine shoots to twist and hence the plants become useless for planting out. On older trees distortion and dieback occur. Because of this damage, it is important to keep the two species of tree separate. Damage by rust fungi is shown in Photographs 30 and 31.

Other fungal diseases of the leaves are caused by Taphrina aurea and Venturia tremulae. The former causes bright yellow blisters and a certain amount of distortion of the leaves. The latter causes black and curling leaves on the aspen, usually when the tree is only a few years old.

Taphrina johannsani is a fungus which attacks the female catkins of the aspen. When the disease is present the capsules become abnormally large and of a yellow colour. The seeds in the diseased capsules are destroyed. Under controlled conditions of fertilization spraying may be carried out to prevent infection by this fungus.

(b). Fungal diseases of the twigs, branches and stem.

Little is known of the fungal diseases of the twigs, branches and stem but Dothichiza populea, Cytospora chrysosperma and Nectria coccinea are sometimes associated with die-back of aspen. Of these three fungi Dothichiza populea is the most serious. It usually occurs on trees which have been weakened by some other cause, such as bad drainage or drought. The fungus causes both canker and die-back. The cankers, however, never become as pronounced as those caused by bacteria, and are therefore not so noticeable. Dothichiza populea gains entry through wounds and causes a certain amount of rot.

Both Cytospora chrysosperma and Nectria coccinea are most probably secondary causes of infection, only attacking after some other infection.

(c). Fungal diseases of the wood of the stem and the root.

Fungal disease of this category is extremely widespread in aspen. It causes a great deal of rot and a great loss of timber volume.

Root rot is caused by Armillaria mellea. This fungus is a major cause of disease in coniferous species as well as in many leaf-tree species. Armillaria mellea enters, primarily, through wounds in the roots, although recent investigations have shown that, in larch, the fungus can enter healthy roots. If the roots of infected aspen trees are examined it is found that, generally, the roots have been badly damaged; the wounds mostly occurring on the upper surface of roots near the soil surface. In these wounds rot is generally present (12). From such wounds rhizomorphs spread towards the stump of the stem, between the bark and the wood. It is interesting

Photograph 32. Rhizomorphs of Armillaria mellea, revealed after removal of the bark on a fallen aspen stem. Grantown-on-Spey.

Photograph 33. The rotted base of a fallen aspen tree showing the w-hite stringy nature of the rot caused by Armillaria mellea. Inverfarigaig, Inverness-shire.

to note that the most usual point of entry seems to be at a distance of between four and seven feet from the stump, and very seldom beyond eight feet from the stump. This is probably because the roots tend to go deeper and are less likely to be damaged where they have greater protection from outside influences. When the rhizomorphs reach the stem, they proceed to advance up the stem between the bark and the wood. In seriously infected trees these rhizomorphs are clearly visible as black interlacing strands, if the bark is removed. This is shown in Photograph 32. Rot occurs in the roots and in the stem, up which it rises to four or five feet in bad cases. The rot is usually centrally placed. The rotted wood initially has a brownish-black colour but later becomes a yellowish-white stringy rot. Intensive infestation can cause the death of the tree, but the fungus continues to live for many years in the stump, from which rhizomorphs spread for several yards.

Photograph 33 is of the splintered base of an aspen tree containing Armillaria rot. The white stringy rot can clearly be seen and has obviously so weakened the stem that it succumbed easily to the effect of wind.

It has not been proved, but it is quite probable that in many cases Armillaria rot spreads through the root system of older trees and infects suckers at a very early age. The fungus seems to occur as widely in strongly growing young trees as in old trees.

The major cause of stem rot in aspen is Fomes igniarius, which is a member of the family Polyporaceae. In the early stage of decay the rotted wood is of a yellowish-white colour. The area of rot is irregular in shape but is normally situated in the centre of the stem. As the decay progresses, the wood becomes soft and whitish, but shows few, if any, cracks. Occasionally

Photograph 34. A fructification of Fomes igniarius on aspen. Boat of Garten, Inverness-shire.

Photograph 35. A fructification of Fomes igniarius in a typical position beneath a branch-stump on an aspen tree trunk. The characteristic cracking of the fructification is clearly visible. Grantown-on-Spey.

the rot is of a brownish colour. A well marked peripheral zone line is usually present. The rot may contain black lines. The fungus always enters through wounds, and most commonly through dead and dying or broken-off branches. The spores germinate with the greatest ease as soon as they meet with exposed wood and otherwise favourable conditions for growth. The hyphae gradually penetrate into the stem itself and extend both from the centre to the edges and longitudinally. The rot progresses both upward and downward from the point of entry at a rate of a few inches to a foot or more per year (22). The fungus eventually forms fruiting bodies (fructifications) at the branch stubs. The fructifications are hoof-shaped, black on the upper surface and a grey-brown beneath. When first formed they are little more than a dark grey-brown crust on the under side of a branch stub, but they increase slowly in size from year to year. As they get older the fructifications become extremely hard and frequently crack. They are difficult to see until they are at least five to ten years old. It has been stated that the presence of a fructification indicates decay from four to six feet above and below the place where it occurs. This, however, cannot be considered a general rule, as obviously a tree with a single fructification two years old, would have less extensive decay than one with a fructification twenty or thirty years old. Typical fructifications in typical situations are shown in Photographs 34 and 35.

Fomes igniarius enters chiefly through branch stubs, and these normally become more numerous as the aspen trees grow older and the lower branches become shaded out. Thus decay tends to increase with increasing age. However, where early damage is sustained, such as

Photograph 36. Fructifications of Stereum purpureum on an aspen stem. The area from which these fructifications arise was found to be rotten and riddled with lead shot - the obvious cause of the fungal entry. Boat of Garten, Inverness-shire.

the eating back of young shoots, the fungus is able to enter the tree when it is only two or three years old. This naturally prevents normal growth from the start.

The presence of stem rot does not always make the aspen useless. If the rot is central and solid enough to take lathe fixings and is not of a very great thickness, the timber can still be used for matches. Thus, although the value is definitely lowered, the trees are still of considerable value, provided the rot is not particularly extensive.

Other species of fungi which cause stem-wood rot are Ganoderma applanatum, Fomes fraxineus, Pholiota heteroclyta, Pleurotus ostreatus and Polyporus sulphureus. These are again, wound parasites and may cause considerable damage locally.

Stereum purpureum occurs commonly on the sapwood of dead branches, and, although it is not important for the aspen, it is important as it causes silver leaf in plum and other trees. Hence it is a danger if aspen are grown in the vicinity of orchards. A rather unusual case of Stereum purpureum fructifications occurring on the main stem of aspen was found in Scotland (Photograph 36). On examination the swollen area from which the fructifications arose was completely rotten and contained several lead shot, which were obviously the initial cause of the damage.

(d). Bacterial diseases of the aspen

The aspen is susceptible to, but rarely attacked by, bacterial poplar canker. This canker occurs on the woody parts of the tree. The initiation of the cankers is due to the bacterium Pseudomonas syringae forma Populea although other bacteria and fungi, including Nectria, may be concerned in the subsequent extension of the cankers. Work done at Cambridge has shown that

Photograph 37. An aspen tree with a large bacterial canker on the main stem. Haugsjā, Norway.

Photograph 38. A badly cankered aspen stem. On the right is a frost crack and within the canker there are numerous exit holes made by insects. The girthing tape at breast height indicates the extent of the cankerous growth. Grantown-on-Spey.

inoculation with a pure culture of Pseudomonas in sterile filtrate of the slime, will produce open cankers similar to those found in nature. (30) The slime contains a toxic substance which causes the green shoot to wilt.

The first signs of the disease are small cracks in the bark from which, in the spring, pale brown bacterial slime exudes. The canker formation then commences. It is the repeated efforts on the part of the tree to heal the wound, and repeated extension of the wound by bacteria and later probably also by fungi, which give rise to the rough and swollen cankers, which are characteristic of the disease. As the disease progresses the cankers may girdle and kill quite large branches or even occasionally the trunk. The disease sometimes kills the tree, but more often cripples its growth and, if cankers occur on the main stem, lowers the value of the timber. A typical bacterial canker is shown in Photogrpah 37.

Quite frequently aspen trees are attacked by a number of diseases simultaneously and in consequence some very poor trees are to be found, particularly in Britain. A typical example of a badly cankered stem is shown in Photogrpah 38. In this the extent of the damage may be gauged by the girth tape which is situated at breast height. As far as can be determined this canker is not bacterial in origin as there is no exudation of slime. Down the right side of the trunk a frost crack can be seen and it is believed that this caused the initial damage. Numerous exit holes of wood-boring insects can be seen. Although this is the most badly damaged stem found, others have been damaged in a similar manner but to a less extent.

In Britain few aspen trees are to be found entirely free from all pests and diseases, but there are great numbers which are not severely attacked and appear quite healthy. The incidence of rot is rather high but otherwise none of the organisms mentioned cause widespread damage continually. This is because serious outbreaks occur only in certain years and are often confined to certain regions. Such epidemics are usually short-lived and the effect on the production is not very great unless deaths are caused.

I.9. PROPERTIES AND USES OF ASPEN TIMBER AND MINOR PRODUCE

Since the timbers of the European aspen Populus tremula and the American aspen Populus tremuloides are so similar, in dealing with the properties and uses, both species will be considered together. Whilst in Europe the greatest demand for aspen is for matches, in America there is a large demand for many other purposes and especially for pulp. Aspen timber is the most useful poplar timber: the present day demand far exceeds the supply. Hence in many areas alternative timbers are being sought. This is particularly so in the match industries of Europe. In America, during and since the second World War, there has been an increasing interest in aspen and at present there is widespread interest in the possibilities of building new industries and extending the life of old ones by the increased use of it. This is particularly so in the Lake States of Michigan, Minnesota and Wisconsin where aspen is a tree of primary importance covering twenty million acres or forty percent of the total forest area (22). The recent increase in the use of aspen in this area came about largely through its availability rather than recognition of its properties although the widely different uses found, indicate that the timber has many characteristics of merit.

In the timber trade all poplar timbers are usually marketed as "poplar" without any differentiation, but since the aspen timber is superior to many of its related species this is a practice which is to be deprecated. For matches and match boxes the European aspen is definitely preferred and hence differentiation is desirable.

(a) Texture, Structure and General Working Qualities.

The wood of aspen has a fine, uniform texture, with indistinct grain markings. It is soft and is an easy wood to work. The uniform texture and absence of a tendency to raised grain makes aspen fairly easy to finish to a smooth surface under favourable conditions. When the wood is wet, however, there is a tendency for the surface to become fuzzy or woolly. This woolliness of the timber tends to cause binding of saws during cutting.

The pores are very small and are visible with the aid of a hand lens. They are very numerous, evenly distributed, and are fairly uniform in size throughout the annual ring, although they become slightly smaller towards the end of the growing season.

Thus the annual rings are fairly distinct to the unaided eye, but when seen with the aid of a hand lens are marked by a band of soft tissue and a zone of denser summerwood, contrasting with the succeeding broad zone of more coarsely textured springwood. The rays are extremely numerous and fine, being only one cell wide and are therefore difficult to see on the end surface, even with the aid of a lens. On the radial or quarter-sawn surface they are visible as thin silvery lines.

The small pores, their uniform distribution, and the inconspicuous annual growth rings and rays all help to make aspen highly uniform in texture and appearance; characteristics which enhance its value for special uses.

(b) Colour and Odour.

As a rule the wood of aspen, both heartwood and sapwood, is practically white. It is frequently streaked

and pith flecks may be present(caused by cambium borer). The inner part of an aspen log is frequently discoloured to a pale salmon brown and is extremely wet. When the sapwood has a moisture content of 100% the discoloured heartwood has been found to have a moisture content as high as 230%. The discolouration is due, primarily, to the early or brown stain stage of the aspen heart rot. However, aspen often contains brownish wood which does not appear to be due to, or associated with decay. The wood around knots is often similarly discoloured and this strongly contrasts with the white wood and at a casual glance makes the knots appear much larger than they are. The source of the darkly coloured wood around knots and in the centre of the tree, which is not associated with rot, is not known. Where dead knots appear, they are often loose and are generally surrounded by rotten wood,

The white wood of well grown healthy aspen is useful for a number of purposes such as food containers, matches, and wood wool (or excelsior as it is called in America).

Aspenwood is practically tasteless and odourless, when seasoned. The green timber, however, gives off a characteristic faint odour. In the forest it is usually easy to detect felling and peeling work on aspen by the smell alone. Because of the absence of odour when dry, it can be used with safety in food containers since it does not impart taste or odour to the foodstuffs.

(c) <u>The Weight and Strength Properties of Aspen</u>.

The aspen is one of the soft wooded, broad leaved trees having a timber which is extremely light in weight when dry. In the green condition aspen timber is relatively heavy, weighing on the average 55 pounds per cubic foot. In the seasoned condition (12-15%

moisture content) aspen weighs, on the average, 26 pounds per cubic foot. The light weight of aspen makes it desirable in containers, matches, toys, wood wool and furniture. Aspen is well adapted where lightness of weight is more important than strength, and where a combination of strength and lightness is desired, for the aspen is strong for its weight. It possesses good strength properties and toughness; properties which make it an excellent timber for matches and match-boxes as it does not fracture easily when bent.

(d) Seasoning.

There is usually little trouble in air or kiln seasoning although careful stacking is necessary to avoid warping and discolouration due to wood-staining fungi. The kiln schedule recommended by the Forest Products Research Laboratory at Princes Risborough is schedule Number V. Unduly high temperatures tend to split knots and also tend to darken the white wood to a buff colour. Difficulty has been experienced in the drying of discoloured heartwood and the brown areas bordering natural defects, without collapse or checking. Aspen shrinks very little during seasoning; less than most other broad-leaved timbers. Once seasoned it shows little tendency to warp.

(e) Nail-holding Power, Gluing, Painting, Polishing and Staining.

Although aspen has a comparatively low nail-holding power, it also has a low tendency to split in nailing. It has been found in tests in America that aspen boxes stood more rough handling than boxes of a number of species with a higher nail-holding power (22). The small tendency of aspen to split at the nails was

apparently sufficient to more than compensate for its lower nail-holding power.

Aspen takes glue extremely well and glued joints that are as strong as the wood itself are easily obtained. Such joints are readily made with any good wood-working glue under good gluing conditions. Tests made at the American Forest Products Laboratory on joints made with animal, casein, and starch glues resulted in an average joint sheer strength of 1,725 pounds per square inch. These tests also showed that aspen is one of the easiest species of wood to glue. The good gluing characteristics of aspen, along with other favourable properties, adapt it to use for core stock and other glued wood products.

Aspen also takes paint well, being equal in this respect to the best of the broad-leaved timbers and also to spruces, firs and hemlocks. However, sound knots in aspen require to be covered firstly by a good priming paint so as to prevent the top coats from drying without gloss over the knots. The knots do not discolour the paint. The brown streaks frequently found in the wood can be covered by applying coatings of good paint or enamel in adequate thickness.

Aspen polishes well but stain, particularly over large surfaces, has a tendency to be patchy. This is because the wood is relatively porous and the stain penetrates deeply but not uniformly. Also if parts of an article are made of aspen, and others of some other wood the aspen is liable to stain more darkly. In addition the grain of the wood lacks sufficient character to make stain and varnish or stain and lacquer finishes particularly attractive.

(f). Resistance to Fungal and Insect Attack.

Both the heartwood and the sapwood of aspen have little resistance to fungal decay. Untreated aspen posts or timber in contact with the soil or otherwise exposed may last only two or three years. However, aspen treated with preservatives has given more than 15 years' use under damp conditions. Where aspen is used in contact with the ground or in a moist atmosphere it should be treated under pressure with a preservative. It is, however, often difficult to get the timber to take a uniform preservative treatment. This is particularly true of aspen in the round and less so for converted aspen timber which appears to treat more satisfactorily.

Aspen timber is liable to be stained by fungi if badly seasoned. Such staining considerably diminishes the value of the timber, particularly for matches, as in this industry white wood only is required.

Whilst there is considerable damage to the timber of standing trees by boring insects (Cossus cossus, Saperda carcharias, Saperda populnea etc.), little damage is caused by insects after convertion. The converted timber is immune from attack by Lyctus spp. because of the small size of the pores, but not from the furniture beetle Annobium punctatum.

(g). Size of aspen timber.

Aspen is, in general, a small sized tree and therefore can only produce a limited amount of wide, clear timber. This fact has a somewhat limiting effect on the uses that can be made of the timber. Thus only a small percentage of long cuttings can be produced and there is only a very limited possible use as a

constructional timber. However, a market for both large and small sized timber can usually be found.

(h) Uses of aspen timber.

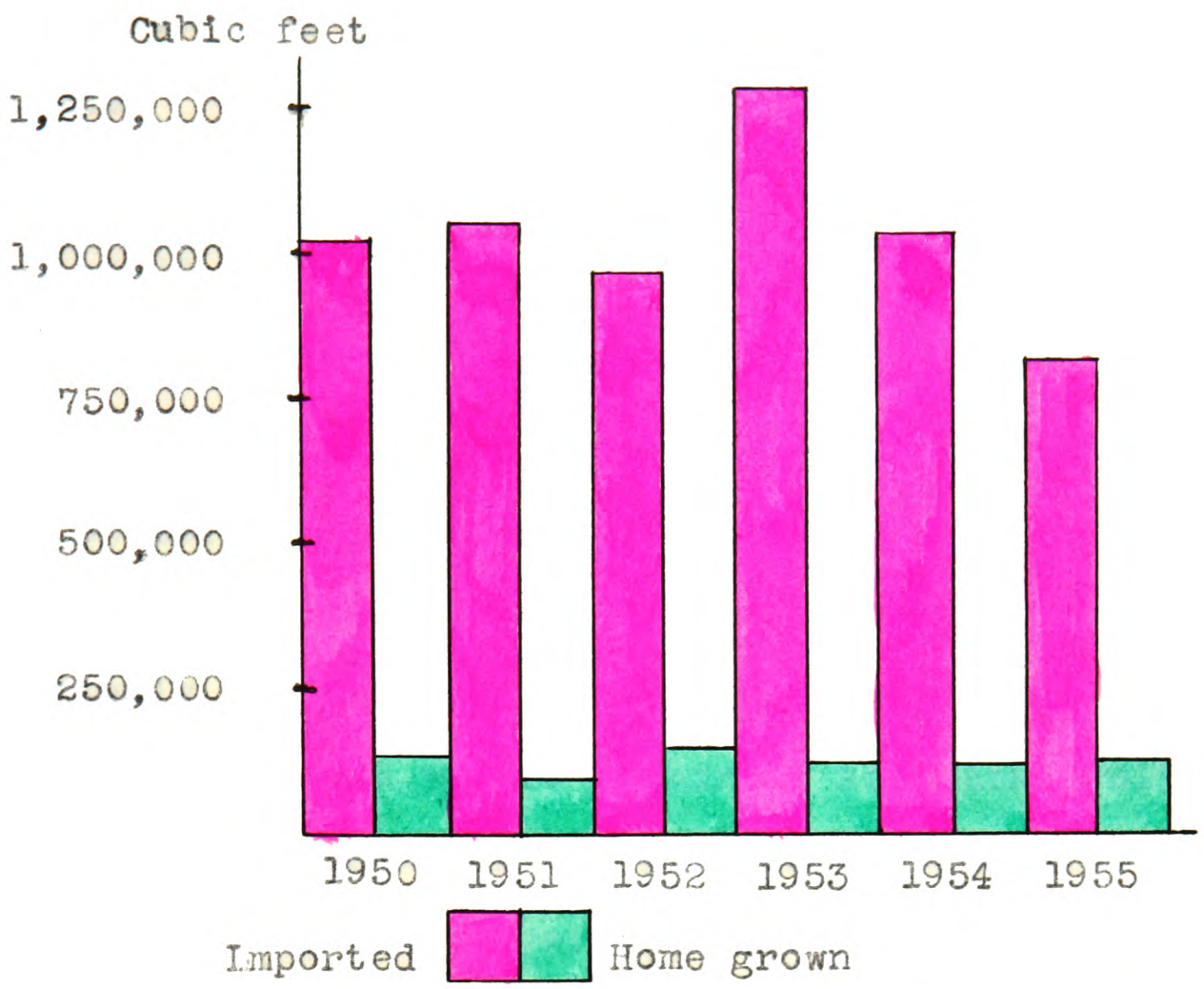
As indicated in the foregoing account, aspen timber can be put to many uses, the primary ones being (i) for matches and match boxes, (ii) for veneers of various types and (iii) for pulp and paper.

(i) Matches and match boxes: - Match making is now one of the most highly mechanised industries, and a brief summary of the process is given in Appendix VIII.

For matches only very high grade poplar timber of large sizes is used. Whilst aspen (P. tremula) is preferred to all other poplars, during the two world wars species other than aspen had to be used in Britain and today they continue to be used. This is primarily because of their large sizes and very fast rate of growth which makes them a profitable tree to grow. Home grown aspen is rarely used owing to the small sizes produced and the high rot incidence. The greater part of the timber used for matches in Britain is now obtained from Canada and is primarily P. tremuloides. Formerly European aspen was imported from Poland and Scandinavia.

Figure 3. indicates the volume of timber used and its source, in the years 1950 to 1955. This diagram includes wood used for chip-baskets which is a branch of the veneer trade (9).

Figure 3. Comparison of the amounts of home-grown and imported poplar timber used in the manufacture of matches and baskets, 1950-1955.



In Britain (Bryant and May Ltd.) the specification for home grown timber is as follows: - Logs must be of veneer quality suitable for rotary peeling. They must be fresh-felled with bark intact, round and straight, free from knots, rot, soft centres, splits, shakes, worm and insect damage and any other serious defects. Logs to be of minimum top diameter (under bark) of 8 inches and a maximum butt diameter of 24 inches. Lengths to be from 7 to 21 feet.

In Norway where P. tremula alone is utilized, a minimum top diameter of 7 inches (narrowest side under bark) is accepted.

(ii) Veneers : - Aspen timber is utilized for various types of veneer and strictly speaking match-making uses one of these. Others are the chip-basket veneers and plywood veneers. All are of a

rotary type and are thus made in a similar manner. Large sized clear timber is always required and specifications tend to be stricter than those for match timber. The use of aspen for veneers is limited as large size logs are scarce, even where aspen finds its optimum. Hence any utilization of it for veneers is carried out only in factories which are equipped to use small-size logs.

(iii) Pulp and paper: - Aspen timber has an average fibre length of 1 mm. and an average diameter of 0.03 mm. Pulp formed from aspen also contains smaller fragments of woody tissue. This aggregate of relatively short fibres and cellular matter is more suitable for use in papers requiring softness, bulk, opacity, good formation and good printing qualities than those requiring toughness, good strength, higher density and harder characteristics.

The great advantage of this outlet for aspen timber is that small sized timbers such as those produced from thinnings can be utilized. In America the major outlet for aspen is found in the pulp industries.

Besides the above, aspen has a number of less important uses.

Aspen timber produces the best quality of wood wool, a substance which is used extensively for such purposes as packing material and as a stuffing for upholstery.

It is a valuable timber for food boxes, dry cooperage, kitchen utensils, toys and when treated it can be used for fencing etc. In America aspen logs are utilized untreated in log cabins. (22). Small sized untreated logs are often used as fence rails. Aspen is also quite suitable for carving, turnery and marquetry work.

In the past aspen has been used in the charcoal industry (particularly in France) and in some places may still be used. The charcoal produced is suitable for use in the making of gunpowder.

There are few minor products of aspen, but the succulent young branches, leaves and bark make a valuable fodder. They can also be used as a mulch.

PART II.

THE PRESENT POSITION OF ASPEN IN BRITISH FORESTRY.

1. THE OCCURRENCE AND DISTRIBUTION OF ASPEN IN BRITAIN.

The aspen was at one time probably general over the British Isles and probably thrived on most of the moderately base rich soils. Owing to the extreme minuteness of the pollen grains any remains of these in peat are extremely difficult to detect with the methods used at present. But in some pollen analysis studies the presence of aspen pollen has been determined. (14). As yet the knowledge gained from this source is of very little value.

At present the aspen is of rather rare occurrence although it is widely distributed. It is a tree which is known to only a few of the general public. Numerous superstitions have been centred upon the aspen in the past centuries and the tree has been regarded, especially in the north of England and parts of the Scottish Highlands, as a tree to be feared. In consequence few workers would touch the aspen. Nowadays these superstitions have largely disappeared. In many areas, especially in parks such as the Windsor Great Park, an occurrence of aspen is promptly cut down and the tree is not tolerated. Both wild and domestic animals readily eat the young succulent shoots and leaves of the aspen and these have consequently aided in the prevention of the spread of aspen by sucker shoots and by seed.

The aspen is, then, an uncommon tree in Britain generally, but in certain areas it becomes quite common. It is usually found in small groups, most probably clones,

scattered amongst other tree species. It is thus generally a constituent of mixed woodland and hence is only able to spread from the edges of such woodlands, where this is possible. Practically all aspen regeneration is by means of root suckers. Occasionally, however, single specimens are found completely isolated from others of the same species and it would be extremely unlikely that such trees arose in any way, but from seed. Viable seed is certainly produced in Britain but very few seeds germinate and fewer seedlings become established.

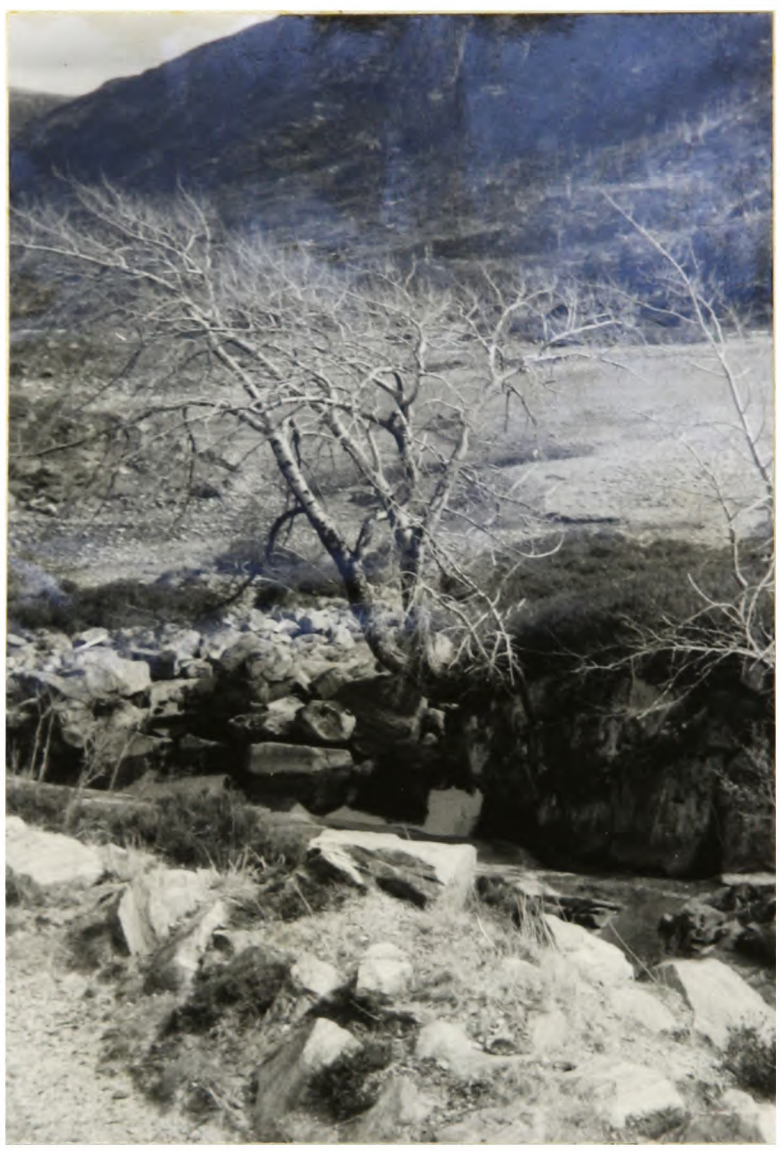
In the south west of England and in South Wales aspen is extremely uncommon, being almost absent. The tree increases in numbers towards the east and north. In south east England it occurs in a few places, usually in groups mixed among birch, oak, ash, willow, hornbeam and beech. Both young and old groups of trees are to be found.

In East Anglia, where natural tree growth is somewhat less than in most other areas, aspen is relatively common. Again, it grows in groups of varying size and is mainly a component of mixed woodland.

In North Wales aspen is not very common but it does occur here and there, usually in small quantities.

In the Midlands, on the heavy soils, and particularly in Warwickshire, Leicestershire and south Shropshire the aspen is fairly common, but never occurs in large numbers. It is present in most woodlands of any size.

Further north, aspen tends to be more well known and is found in most areas, but only in small amounts and it seldom grows to a height of more than thirty five feet. Aspen has been recorded at an altitude



Photograph 39. An aspen tree growing between burn-side rocks in an exposed situation. Ross-shire.

of 1,600 feet in the Pennines of Yorkshire.

In Southern and Central Scotland aspen is not common but in some areas of the Highlands it is quite common and assumes predominance in mixture with birch in a number of places. This mixture forms one of the natural woodland communities of Great Britain. (Anderson 1.). The mixture, in most instances, is only a remnant of a former more extensive community which must have been characteristic over much of the drier areas of the Scottish Highlands.

The main region where the aspen grows at present is in the Central and Eastern Highlands, but in the West Coast Region aspen occurs occasionally.

In Ross-shire and Sutherland occurrences decrease towards the north. Along the west coast of Sutherland aspen occurs in a few places and mainly close to the sea. At Drumbeg aspen occurs within ten yards of the high tide mark and near Scourie there are several aspen within fifty yards of the sea. In this wild western country with its rocky outcrops and many lochs the aspen occurs in very small groups (2 or 3 trees), in small pockets of soil usually close to water. The trees are rarely more than ten or fifteen feet in height. A typical tree of such situations is shown in Photo-graph 39.

In a few areas, such as that around the Kyle of Sutherland and around Balmoral, the aspen becomes more frequent, but it is only in the area of the Great Glen and the Spey Valley that the aspen can be considered a relatively common tree. It is in these two areas that investigations into the growth of aspen have mainly been confined. The valleys further south also contain a sprinkling of aspen.

In Ireland aspen is recorded in every county, but is by no means a common tree.

The aspen is thus very widely distributed in the British Isles, but its occurrence is extremely sporadic and in no area can it really be considered a common tree. It is everywhere a tree of very poor form, although it tends to be slightly better in this respect, as well as in growth, in the better stocked areas of Scotland.

From the above account of its distribution it is clear that as the aspen occurs in all regions of Britain, apart, perhaps, from the extreme south west, it is capable of growth in a variety of climatic types and also on a great variety of soil and site types. The fact that the tree grows on nearly all sites but the extremely acid ones does not mean that it is a suitable species for all of these sites. If the aspen, in Britain, only grew on the sites which really suited it, the general opinion of the tree (which is very poor at present) would be very much better. Even in the areas where it is most commonly found, the sites it inhabits are only doubtfully suitable. As a colonizing species it is capable of growing on a variety of sites, but if the tree is to be grown for timber production the correct selection of site is of the utmost importance.

The occurrences of aspen noted in the two main aspen areas are shown on the map in Appendix I. It should be noted that the greater amount of aspen occurs in area I, the central section of the Spey Valley. Here aspen occurs chiefly in two types: (a) In small self-contained groups most frequently situated on the edge of woodlands of other species, and (b) In mixture with other species. In the latter case the mixtures tend to follow a roughly group-wise plan but the groupe are

seldom, if ever, pure and are not as dense as the self-contained groups of type (a). In area II, the Central area of the Great Glen, the occurrences are more frequently of a self-contained group nature and in many mixtures that occur, the aspen is a very subsidiary species occurring only occasionally and not in groups of more than three or four trees.

In area I. the mixtures are primarily of birch and aspen. Despite the abundant natural Scots pine in this area, in only one place is a mixture of this species with the aspen recorded. Whilst rowan occurs quite frequently in the pine stands, the aspen occurs only rarely in them.

The birch and aspen mixtures form a community type and in general the birch occupies the wetter areas in the woodlands, whilst the aspen occupies the drier areas. It is thus characteristically found on the higher ground, the knolls and drier slopes in the birch wood. The birch is seldom anything but scrubby in nature and usually the aspen stands with the majority of its crown layer above the birch.

As can be seen from the map, even in the main aspen areas, the aspen only occurs sporadically. It is generally confined to the slopes of the hills surrounding the rivers and lochs or the flatter, often alluvial, areas in the valleys. Thus it primarily occurs in sheltered situations, although the aspen is found up to the tree limit in some places.

2. THE DISTRIBUTION OF SEXES.

As has been stated previously, the aspen is a dioecious species as it has both male and female trees. As the tree reproduces so easily and rapidly by means of vegetative root suckers, it is frequently found that all the trees in a group originate from one stem and are consequently of one sex only. Root suckers can occur from the roots of a tree of only two or three years of age and hence, a group of trees can appear to be of uniform age and still all be produced from a single original stem.

In order that fertilization should occur it is necessary that both male and female trees are present in the same locality. It could happen that all the aspen found in a specific area are either male or female and fertilization is very unlikely. The pollen grains are, however, extremely light and can be carried great distances by the wind, but, if the sexes are isolated from one another, only a few, if any, pollen grains will reach female catkins and any fertilization will be insignificant.

Sexual reproduction can, of course, only be brought about after fertilization and since the spread of the aspen to entirely new areas is dependent on seed, the presence of both sexes in any one vicinity is important. Hence a knowledge of the distribution of the sexes will indicate the likelihood of fertilization, the production of seeds, and the spread of the tree species by sexual means, to new areas.

The flowering of aspen is usually sufficient each year to produce a very large amount of seed, but as with other tree species flowering does not take place

in equal amounts each year. As has been previously stated, with aspen a good flowering year usually follows a hot summer. The summer of 1956 was a poor one and consequently in the spring of 1957 fewer catkins than normal were produced. In addition to this the catkin buds at the time of their flowering suffered severely from frost and most dropped from the trees. Therefore only very few catkins were produced. Thus studies on the distribution of the sexes were made impossible.

However, both species have been found to be present in different vicinities in both area I and II on the map in Appendix I. This shows that spread of the aspen by seed is not impossible in these areas. In the past a certain amount of seeding must have taken place as solitary trees are frequently to be found in situations where aspen have not been known for many years.

Sexual reproduction of aspen is thus quite possible in Britain and could prove to be a useful means of obtaining additional stands of aspen. It takes only one successful seedling to form a stand of aspen in a new area, because that one seedling will itself reproduce vegetatively. The conditions required for successful seeding, or rather establishment, are exacting, and an indication of these in Norway is given in Part III. 1.

Photograph 40. A group of over-mature aspen trees (between 80 and 110 years). The crowns are heavy and many branches are dead or broken. The trees all contain rot. Cromdale, Morayshire.

Photograph 41. A group of over-mature aspen trees seen from a distance. The nature of the crowns which tend to have a drooping habit is visible. Grantown-on-Spey.

3. THE BEHAVIOUR OF ASPEN IN NATURAL OCCURRENCES IN BRITAIN.

This section deals mainly with the area covered by the map in Appendix I.

Old, over-mature trees are distributed widely throughout the main aspen areas I and II. (see map). It is difficult to estimate the ages of these trees, but ring counts from bore spills reveal that trees such as those in Photograph 40. are between 80 and 110 years of age. The old trees are all of very poor form as is shown in the photographs. The crowns are extremely broken and many large and dead branches are retained. This type of growth is typical and is shown also in Photogrpah 41.

A large number of the trees bear fructifications of the fungus Fomes igniarius whilst a few bear fructifications of Ganoderma applanatum. Others show the presence of rot in the timber and frequently there is considerable damage visible on the stems and branches. All the trees in these areas, practically without exception, show evidence of the presence of wood or root-rotting fungi, extensive damage by wood-boring larvae and other signs of disease and poor growth. It is almost possible to distinguish all the aspen stems over middle age by the varied lichens which grow on them, in particular, the yellow wall lichen Xanthoria parietina which is extremely common.

It is quite remarkable how much of the old aspen is growing in exposed places. It cannot, in many cases, be determined whether they were so exposed in their youth. It is probable that trees such as those in Photograph 40 grew up amongst trees of other species

which have since been cleared, the aspen being left for superstitious reasons.

The old aspen usually occur in groups. They reach, as a rule, a height of about 30 feet and occasionally 50 feet. It appears that the trees reach their maximum height growth between 50 and 70 years of age. The crowns tend to expand, becoming wider and denser at 40 or 50 years, and instead of growing appreciably taller the branches tend to become more pendulous and the crowns, whilst not flattening to any marked extent, tend to arch over. This effect can be seen in Photograph 41. Accompanied with this stoppage in height growth and extension of the crown there is naturally an increase in girth. In the Grantown-on-Spey area the maximum height growth (30 - 55 feet) is reached when the diameter at breast height is between seven and nine inches. After which the heights remain approximately the same, but the diameters increase up to between eleven and fifteen inches. One very large old tree with a diameter at breast height of 29 inches (Quarter girth 23 inches) is growing in Glen Beg near Grantown-on-Spey. This tree, however, is divided into a number of very large branches at a height of ten feet and thus there is only a short bole. The tree is probably well over 100 years old.

Large diameter sizes can therefore be produced. Normally, however, there is only a short length of bole. A few exceptions are found on more favourable sites and normally in mixture with other trees. Examples are shown in Photographs 42 and 43. The first is a photograph of trees showing fairly good growth and slightly better form than the trees growing in more exposed places. The area is flat and is close to the river Spey. The soil is a moderately evolved brown forest soil. Large and small rounded stones are plentiful in

Photograph 42. Aspen trees showing fairly good growth and a form which is better than the average for Britain. Grantown-on-Spey

Photograph 43. Aspen trees growing amongst birch scrub at an altitude of 1,000 feet. The growth and form are fairly good. Grantown-on-Spey.

the upper layers, but at about 18 inches there is a coarse sand layer. There is a half inch litter of leaves and other detritus and a good humus layer. Worms and moles are present. The area is probably subject to occasional floodings and is moist at all times but drainage is good. The vegetation is made up of grasses, (Aira caespitosa, Festuca ovina and Agrostis canina with occasional Molinia caerulea) mosses, (Hylocomium triquetum and H. splendens), a few herbs (Anemone nemorosa, Conopodium denudatum and Galium saxitale) and bracken. The woody vegetation is composed of birch and aspen. The birch reaches a height of about 40 feet and is extremely poor and scrubby. Most of the aspen are between 45 and 50 feet, but the largest (central in the photograph) is 55 feet in height. This tree has a diameter of 17 inches at breast height.

The second photograph shows aspen, again in mixture with birch, at an altitude of 1,000 feet on a fairly steep east-facing slope. The vegetation is similar to that on the previous site, but here the dead leaves lie in a thicker mat. The soil is shallow and is a brown forest soil. There is more evidence of leaching than on the previous site. The area is moist as water runs into it from above where the terrain is steeper.

The aspen trees are quite healthy and the tops show little sign of old age and decay. Lichen is not as plentiful on the trees as in other aspen occurrences in the area. The height growth is fairly good by British standards, the tallest trees being just over 50 feet in height and well above the height reached by the scrubby birch growth. The largest tree has a

Photograph 44. A group of unhealthy aspen trees which was formerly surrounded by pine trees. Once the protection afforded by the pine trees was removed many breakages occurred amongst the aspen. Nethybridge, Inverness-shire.

Photograph 45. A small group of aspen of very poor form growing on a dry knoll. Grantown-on-Spey.

Photograph 46. An aspen tree, probably of seedling origin, growing on the banks of the Spey. The tree is at the stage when its crown is enlarging and becoming bushy. Grantown-on-Spey.

diameter of 16 inches. Younger trees are present in this area, probably of 40 years. They have almost reached 50 feet in height and have diameters of between ten and eleven inches.

Another group of large aspen which stand alone at present, but formerly formed a group on a damp site amongst a mature pine stand, are shown in Photograph 44. This group, as can be seen, is far from healthy, fallen stems, and broken stems and branches being visible in the photograph. These breakages have mostly occurred since the removal of the protective pine stand. The ground flora consists of Aira flexuosa, feather mosses, and Blechnum spicant. The trees here reach 60 feet but have very poor form and it is only the surrounding stand that has drawn them up. There is a very high incidence of rot. The surrounding clear-cut area is largely re-stocked with birch and rowan, but some aspen suckers appear near the large trees and, in particular, one small group mixed with rowan is showing very good initial growth.

A small group of very poor aspen is shown in Photograph 45. This occurs on a dry knoll surrounding which is a wet area covered by birch. The aspen trees are decadent and dying and are absolutely rotten. Such growth is more typical than that of the larger trees mentioned previously. This site is exposed to the south-west (right of photograph) and the effect of this exposure can be seen in the photograph. In the more sheltered and slightly moister areas around this knoll young aspen suckers are growing reasonably well.

A single tree which is probably of seedling origin is shown in Photograph 46. This tree is at least 100 yards from any other aspen, but of course it is difficult to know the conditions forty or fifty years

Photograph 47. Showing the extreme poorness of aspen growth, which is quite common in Britain. Grantown-on-Spey.

Photograph 48. An aspen tree showing fine growth and good form. A girth tape can be seen at breast height on the stem and this gives an indication of the size of the tree.

Fort Augustus.

Photograph 49. Sucker growth from the large tree depicted in Photograph 48. Good growth and form is again indicated. Fort Augustus.

ago when the tree originated. The photograph indicates the stage of growth when the crown is enlarging and height growth terminating. The site, as can be seen, is steeply sloping down to the river below. The vegetation is primarily of grass and is poor. Suckers from this tree are browsed back. Birch, hazel, juniper and alder scrub occur in the area.

The extreme poorness of growth which is quite common in the Grantown-on-Spey area can be seen in Photograph 47. The lichen-covered, small branchy trees in the foreground are aspen and should be compared with the better growing aspen on the left in the background. The difference is striking, but the sites are similar and are of the usual grassy nature. It is feasible that the two types are connected by roots, but owing to the extreme differences in growth this is most unlikely.

Old aspen growth does not occur much in the central Great Glen area, (area II on the map) but where it does occur it is similar in type to that in the Spey Valley. Typical old aspen are growing at the head of Loch Garry.

Some fine growth is to be seen however, in a small group of aspen in a rather inaccessable place on the southern side of Loch Ness below steep cliffs. The actual site is a rocky slope covered by mosses and grasses. The trees, here, appear perfectly sound and have good form. The largest, along with some suckers, is shown in Photograph 48. This tree has a height of 50 feet and a diameter at breast height of 10 inches. The height to the first branch is 25 feet. The tree is between 60 and 65 years of age. Younger 20 to 35 year old sucker growth nearby is shown in Photograph 49. This again, is of fine form and has good growth and as

Photograph 50. Aspen in the valley of the River Avon. These trees show very fine form (although the branching is rather heavy) and growth. The complete absence of lichen on the aspen stems should be noted, the bark being clean and bright. Lichen is, however, present on the scrubby birch (right). Banff-shire.

far as can be determined is free from rot.

The best type of aspen found is that growing in a small area in the valley of the river Avon in the county of Banff. This aspen is shown in Photograph 50. It again occurs in mixture with birch, but here the ground vegetation is different to any of that found elsewhere under aspen. It consists of a carpet of Hylocomium mosses with fine grasses. Blechnam spicant, Vaccinium myrtillus and V. vitisidaea are common. Galium, spp., and Anemone nemorosa are frequent, and Erica cinerea rare.

The soil appears similar to that already mentioned, there is slight leaching. The aspen are remarkable for the lack of lichen and extremely bright and clear bark. The branching is unusual as can be seen in the photograph. All sizes of tree are represented in the wood which is on a steep north-westerly sloping site. Only one tree shows externally the presence of fungi and there is little incidence of rot.

This better type of tree has only been found in one small area of woodland. The reason for this is obscure; it is unlikely to be solely due to the slight changes in the site type and more probably the growth results from a seedling produced by a crossing of trees from different areas. Unfortunately the sexes of the trees were not determined in 1957 as the trees bore no catkins. It is quite likely that all are of one sex. This type of tree would be useful in aspen tree breeding, especially if it is female, as then males from other European races could be crossed with it in the hope of producing a better strain of tree for British conditions. This matter is dealt with further in Part IV.2.

Photograph 51. Poor aspen sucker growth. Delliefure, Morayshire.

Photograph 52. Typical root sucker growth. The difference in branch-form between the aspen (centre) and the birch (right) can be clearly seen. Kingussie, Inverness-shire.

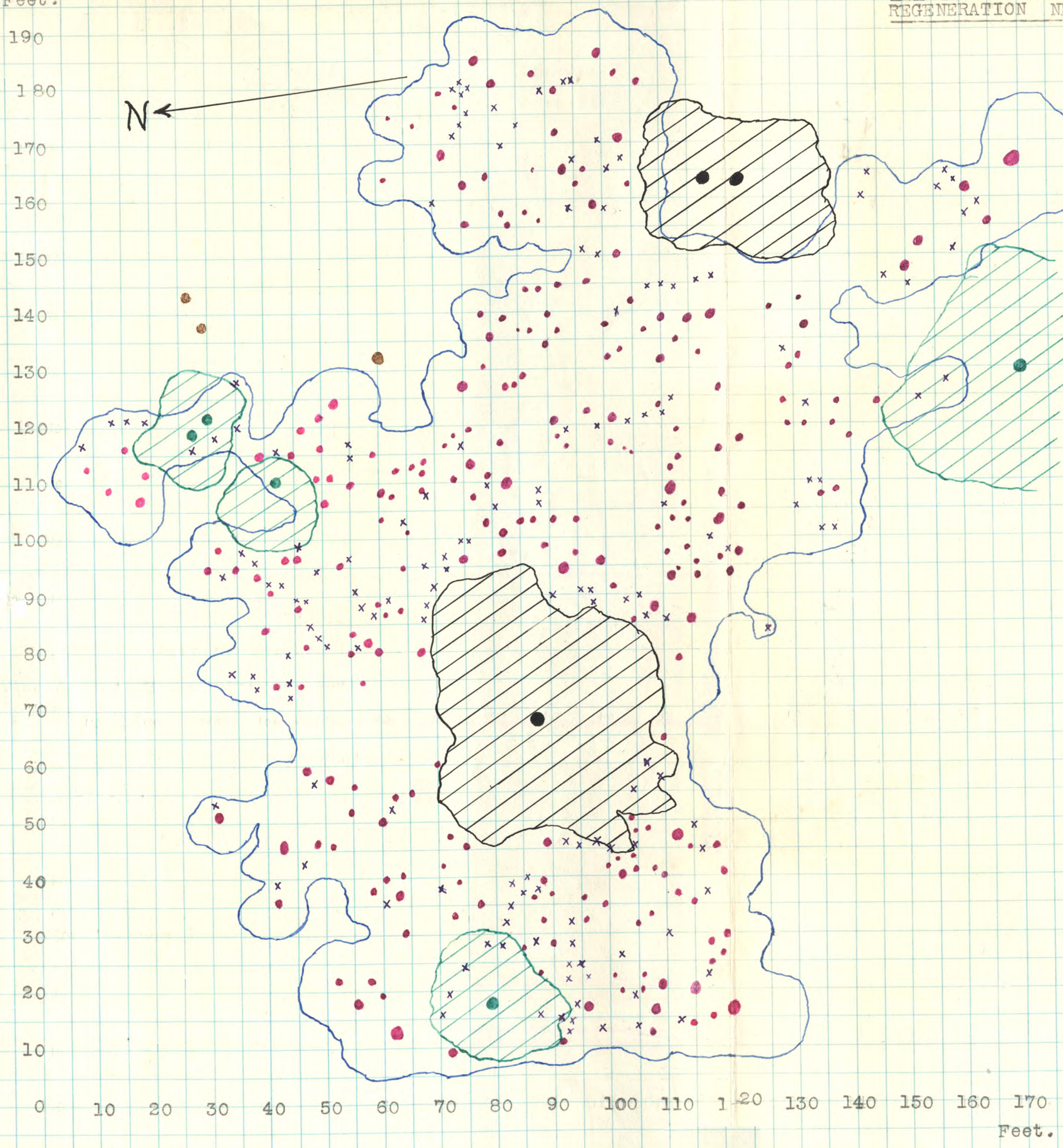
The young growth of aspen in Scotland is, as a rule, quite good. A few exceptions where the growth is somewhat straggly and uneven can be found as in the small group depicted in Photograph 51. Suckers of poor shape are shown on both sides of the road. In this small area (1/3 sq. chn.) there are 50 stems of which 12 are dead. The more normal type of root sucker growth is shown in the photograph taken near Kingussie (Photograph 52). This shows suckers of varying sizes. The foreground is covered by young suckers most of which have been browsed back. In the centre are a few large suckers and behind them there are smaller suckers. An interesting comparison between the typical upright aspen branching and the more horizontal and pendulously-ended branching of birch (right) is shown in this photograph.

Small groups of suckers of this nature occur widely, but sucker growth around many older trees or groups of trees is prevented by grazing.

Less often, more densely stocked useful groups of aspen sucker regeneration are found. A fine example of dense sucker growth is shown in Photographs 53 and 54. These show respectively the parent aspen tree situated in old parkland now under cultivation and the abundant sucker growth produced from it beyond the fence in an area which has been free from interruption, and a view of the interior of the aspen sucker stand. This regeneration which is 15 years old occurs at Old Scone in Perthshire and is of comparable amount to that obtained in Scandinavia. The form of the young growth is, however, poor and it is noticeable that frequently three or four stems arise from the same source. The height growth, which averages 16 feet, is not good for the age of the stand. Treatment at an earlier age

FIGURE 4

PLAN DIAGRAM OF A GROUP OF ASPEN SUCKER REGENERATION NEAR AVIEMORE, Ref. NH 882081.



LEGEND:-

Old aspen trees:-

Area covered by their crowns:-

Dead old aspen stumps:-

Birch trees:-

Area covered by birch crowns:-

Live aspen suckers:-

Dead aspen suckers:-

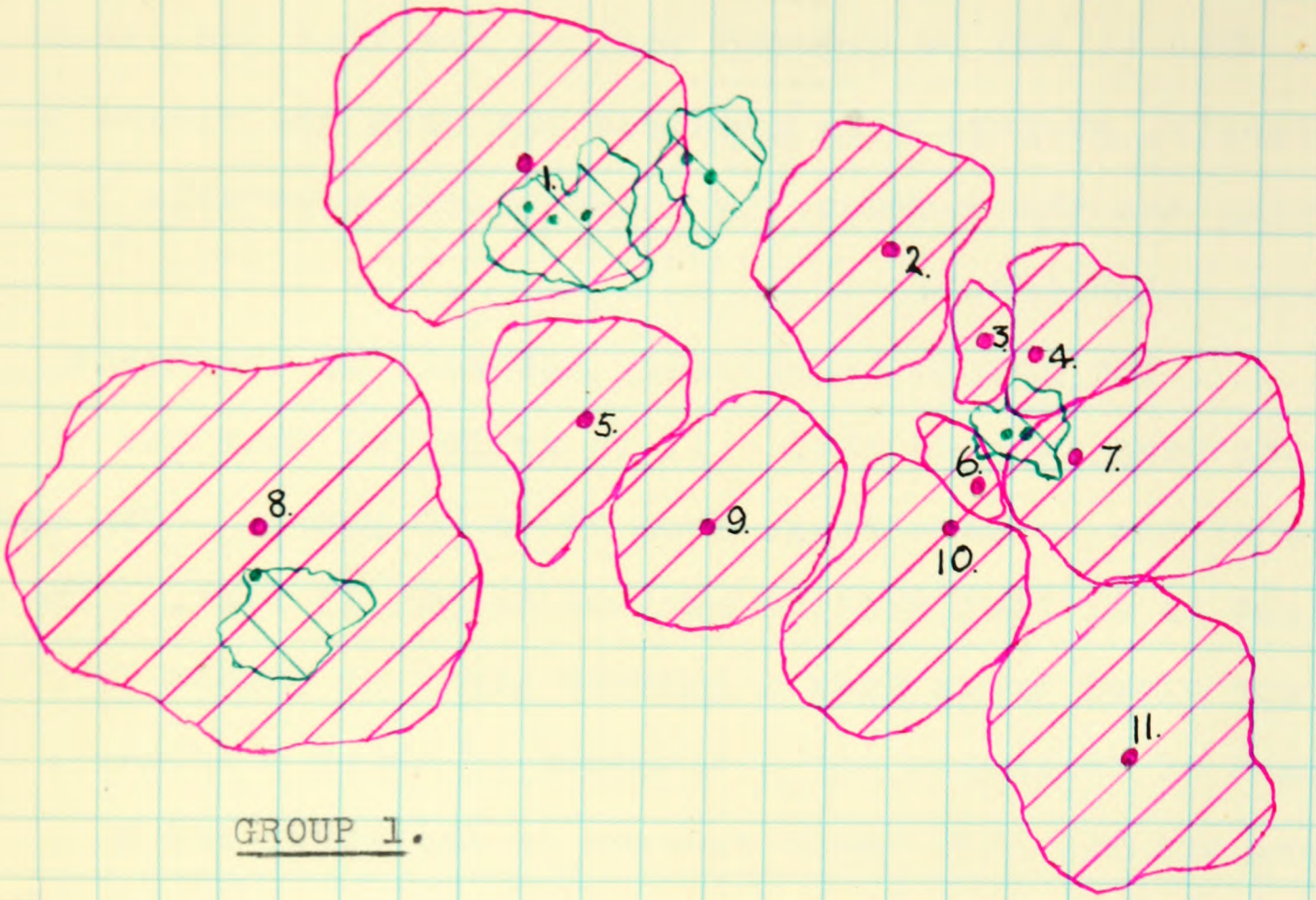
Limit of sucker regeneration:- (large-size)

back continually as the area is grazed by sheep and horses. The suckers are thus prevented from growing. From this it can be deduced that at the time the large successful suckers were produced the area was closed to grazing and the suckers, in consequence, were able to become established.

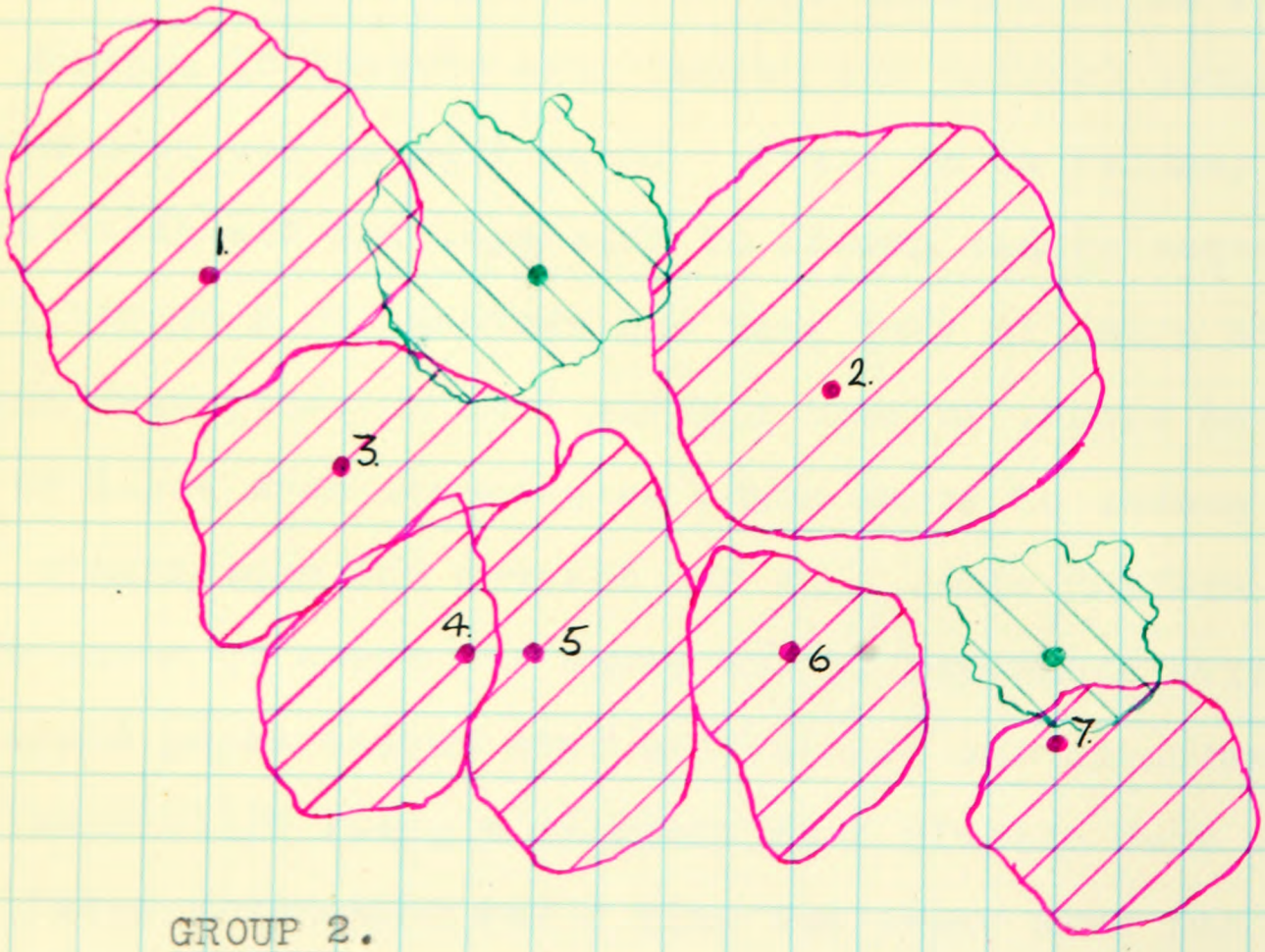
The growth is entirely natural, no treatment having been carried out. It is estimated that the ages of the suckers range from 20 to 30 years. The mean height is 27 feet and the maximum height 35 feet. The larger sized trees have a quarter girth at breast height of 4¼ inches (or a diameter of about 5 inches). There are 264 live aspen suckers in the group and a further 166 dead aspen suckers. Thus at present the regeneration has a density of about 1,056 stems per acre, whilst about 5 years ago the density was 1,640 stems per acre, (taking the actual area covered by suckers as a quarter of an acre). These figures are reasonable for aspen sucker growth of this age, but the distribution of the stems is very poor and whereas, in a properly managed stand, thinned lightly from an early age, the same number of trees might be present, each would be of a similar size. In the diagram the approximate relative diameters of the stems are shown by means of a variation in the size of the dots representing them. These show clearly that there is a great difference in size and that there are only a few reasonably sized specimens (3-5 inches diameter), and these are not distributed evenly. Thus, natural growth of aspen in such groups is not very good as only a few trees are able to progress really satisfactorily. The growth of the majority is poor but had thinning been carried out at a relatively early age the results would undoubtedly have been better.

FIGURE 5

PLAN DIAGRAMS OF GROUPS OF ASPEN SHOWING THE AREAS OF THE PROJECTIONS OF THE CROWNS



GROUP 1.



GROUP 2.

SCALE:-

One square =one sq. yd.

LEGEND:-

Aspen trees:- 4.

Area covered by aspen crown:-

Scrub birch trees and crowns:-

The distribution of the dead trees is interesting. Whilst most occur in the densest regions and under shade where they have obviously been killed owing to suppression, some occur on the margins of the group. Death in these cases is not, as a rule, caused by suppression but comes as a result of damage to the trees by large animals which eat the bark away. Some root rot is also present as some trees have been wind-blown thus exposing rotten roots.

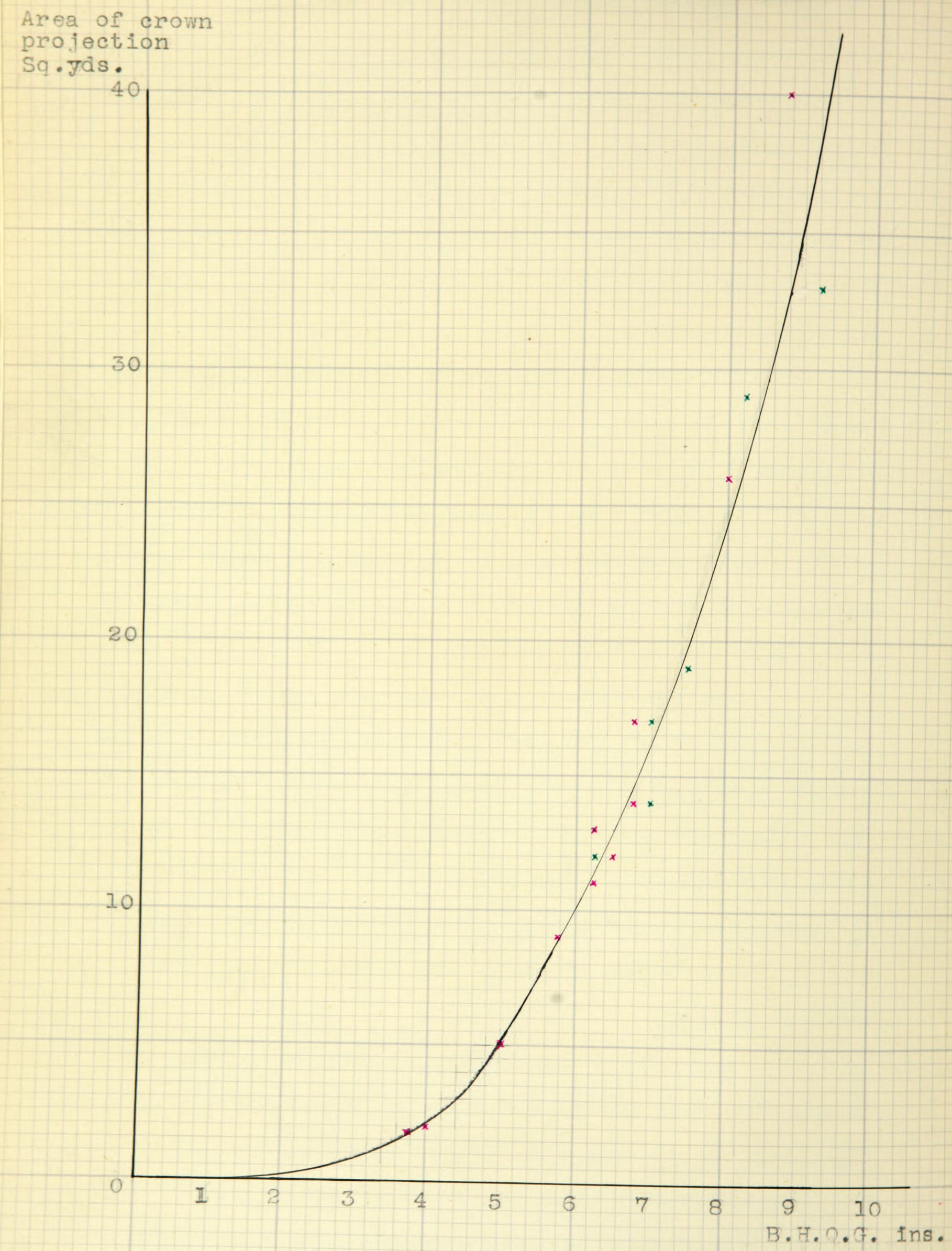
The general growth of this group indicates that natural sucker regeneration can be successful in Scotland. Once successful sucker regeneration is obtained it should be thinned lightly and regularly so as to obtain a more uniform spacing and hence more symmetrical crowns, better utilization of the available light and better growth.

The relationship between the crown development and the growth of the aspen stem in diameter or girth can be obtained from the plan diagrams in Figure 5. These show two different natural groups of middle-aged aspen growing near Grantown-on-Spey. The sites are comparable. They carry the usual grass-moss vegetation found under aspen in the area, and lie on boulder till.

Group 1. is slightly younger than Group 2, but within each group the ages of the trees are the same. The former group is composed of eleven aspen trees with heights varying between 30 and 40 feet and the latter is composed of seven aspen trees with heights varying between 40 and 45 feet. Both groups occur in a birch-scrub woodland, but the birch is nowhere more than 25 feet in height and where it occurs in the groups it does not affect the aspen crowns.

FIGURE 6

GRAPH SHOWING THE RELATIONSHIP OF THE AREA COVERED BY THE PROJECTION OF THE CROWN AND THE DIAMETER



Trees of group 1:- ×

Trees of group 2:- ×

The area covered by the projection of the crown and the quarter girth at breast height of each tree is given in the following table.

The trees are arranged in descending order of crown areas.

TABLE 10. Relation of area of projection of crown to growth in girth in two groups of aspen.

	Tree No.	Area covered by crown. Sq. yds.	B.H.Q.G. ins.
Group 1.	8	40	8¾
	1	26	8
	11	17	6¾
	7	14	6¾
	10	13	6¼
	2	12	6½
	9	11	6¼
	5	9	5¾
	4	5	5
	3	2	4
	6	1¾	3¾
Group 2.	2	33	9¼
	1	29	8¼
	5	19	7½
	3	17	7
	6	14	7
	4	12	6¼
	7	12	6¼

These figures when plotted on a graph give a smooth curve as is indicated in Figure 6.

The investigations show clearly that there is a relationship between the crown development and the diameter growth. Those trees which have large symmetrical crowns, the growth of which has not been markedly impeded, show a greater diameter growth.

This clearly indicates that aspen would respond readily to regular thinnings which provide the crown with adequate room for development. Too much room, however, would not be beneficial as height growth would be reduced and heavy crowns produced. It is a well formed symmetrical crown which is necessary for good

aspen growth. Such a crown should not, however, be of a heavy or bushy nature.

Whilst natural selection, to some extent, favours the better trees, it will not, as a rule, give such good results as artificial selection by thinnings. In natural growth large, vigorous, coarse and heavily crowned trees, often called "wolf" trees, frequently dominate a stand and reduce the growth of their lesser neighbours which are often trees of better all-round quality. In artificial tending operations such trees would be removed and all trees which show good form and growth would then be given an equal chance of producing the best possible quantity and quality.

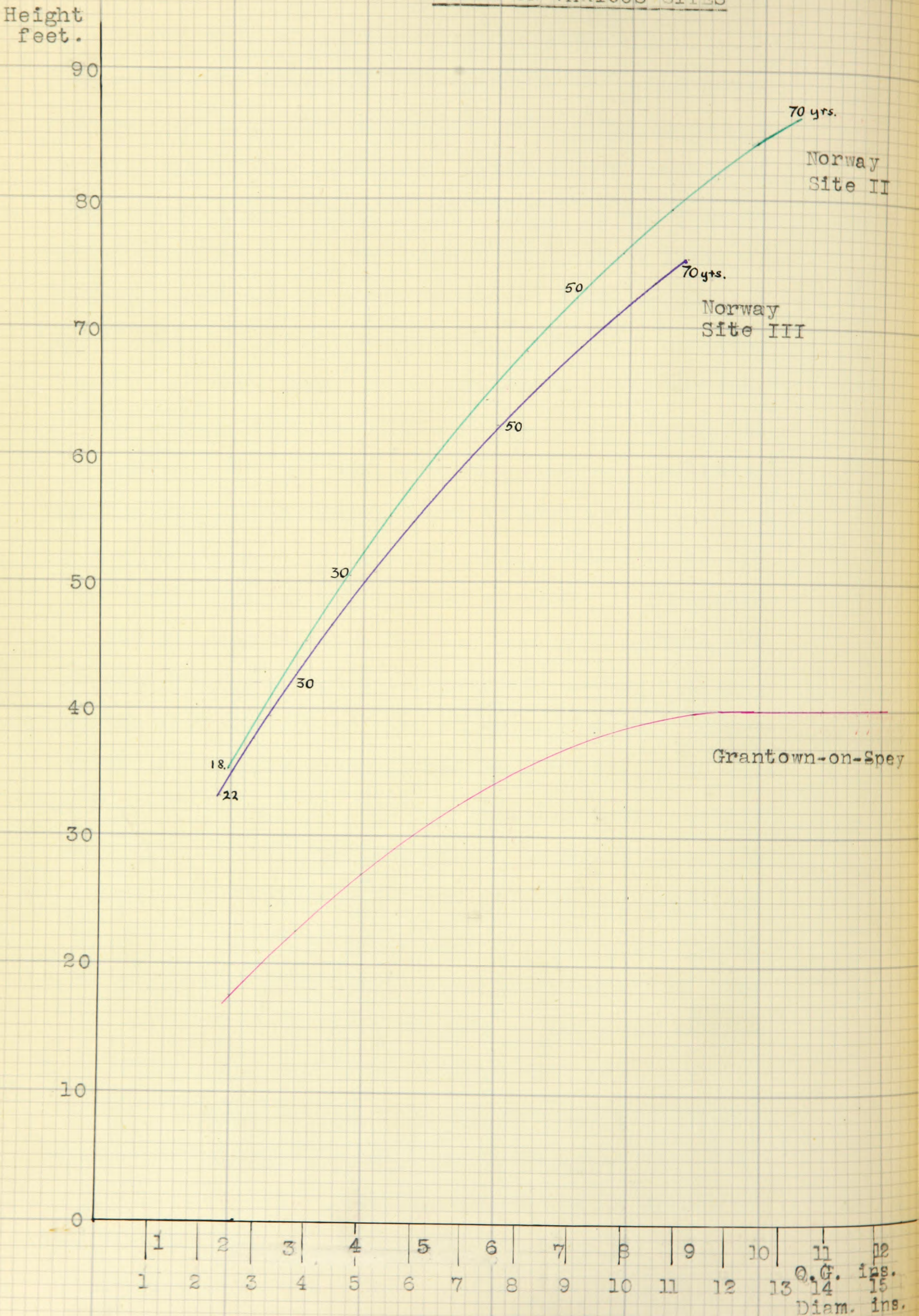
The study of aspen growth in Britain is made difficult because accurate ages for the aspen cannot be obtained. This is because (a) the histories of the stands, i.e. the date of their origin, is not normally known, (b) aspen is only rarely cut down as timber (as a rule it is left to die and fall naturally), and hence very few stumps on which ring counts could be made are available, and (c), the use of borings is difficult owing to the eccentricity of the stems and the high incidence of rot which obscures the rings. Furthermore, the use of borings is always liable to lead to fungal infection; a factor which should be avoided in aspen as much as possible.

Some stem borings have been made, however, in order to obtain data on (1) the approximate ages of variously sized stems, (2) the increment, and (3) the incidence of rot in some areas.

As the ages of the British aspen cannot easily be determined accurately in a practicable manner, no details of height or diameter growth with increasing age can be given. But both height and diameter

FIGURE 7

HEIGHT/DIAMETER (GIRTH) CURVES FOR ASPEN ON VARIOUS SITES



measurements are easily obtained. The curves shown in Figure 7. give an indication of the average growth of natural aspen in the Grantown-on-Spey area in comparison with the average growth of treated aspen on medium-good (II) and medium-poor (III) sites in Norway. The upper point on each of the Norwegian curves is for 70 years. The 70 year value on the Scottish curve is unknown. A very approximate value is obtainable from the following data taken by ring counts of borings made in a very limited number of trees: -

Breast Height Diameter in inches	Approximate Age in years.
9.5	54
10.5	65
10.75	70
11.0	69
11.5	72
12	76
12	73
13	86
14	89

From these data the 70 year value lies between 10.5 and 12 inches of diameter. Thus in diameter growth the Scottish aspen is comparable with aspen on site III in Norway. But the Scottish aspen is shown to be extremely poor in height growth.

Because aspen is not utilized in British forestry today, no investigations into the growth and volume production of aspen have been carried out in Britain. There are, therefore, no volume or yield tables applicable to British aspen. It often happens that a volume table constructed for one species is suitable for another also. In Britain the only published volume tables which might be applicable to

aspen are the Forestry Commission Volume Tables for birch and for small hardwoods. That for birch is inapplicable owing to the pronounced taper in the lower portion of the stem and hence birch trees of a given breast-height quarter-girth and stem-length usually have smaller volumes than trees of other species, including aspen. The Small Hardwoods Volume Table is only applicable to the slow growing leaf-tree species such as oak and beech and the tables only go up to a quarter-girth of six inches.

In Norway, an aspen volume table has been prepared and is given in Appendix VII. This table has proved accurate all over the aspen region in Norway and has also given accurate values for aspen in Sweden and Estonia. The extreme poorness of aspen growth in Britain is shown by the fact that out of 102 typical trees growing near Grantown-on-Spey only 42 conform to the Norwegian Volume Tables. These 42 are all small trees: of the 40 trees which have a breast-height quarter-girth of six inches or less, only four have a height which is too small for the table. Only six trees of the remaining 62 samples are tall enough to conform to the table. This clearly shows that the British aspen has a very poor height growth after a quarter-girth of five or six inches has been reached. Growth in youth, however, is quite reasonable in comparison with Norwegian standards. On the whole, the Norwegian Volume Table cannot be used to compute the volumes of standing aspen in Britain.

At present the construction of a general volume table for British aspen would not be worth-while. In the few areas where aspen is relatively common local volume tables could be constructed and utilized. To do this accurately would involve a

detailed analysis of a large number of sample trees and this has not been attempted in this work. However, by the use of an approximate form factor a local volume table has been constructed for the Grantown-on-Spey area, and this gives an idea of the aspen growth there. The form factor used, is that used both in Norway and Sweden, namely 0.5.

The height/diameter (girth) curve for aspen at Grantown-on-Spey shown in Figure 7 represents the average measurements obtained from 102 sample trees. The volume table is based on this curve. The method of construction of, and the volume table is shown in Appendix III. The table is based on the breast height dimension only, and assumes that trees of the same breast height dimension have the same average form and height.

The annual volume increment percent for aspen in the same area near Grantown-on-Spey has been determined by Borggreve's Method. For this, a total of 40 trees with diameters varying between 5 and 11 inches were taken at random as sample trees. On each the mean diameter over bark, the mean bark thickness and the mean number of rings in the last inch of bore spill were measured. The calculation is given in Appendix IV. The percentage volume increment was found to be 4.2

Over the corresponding diameter range, the percentage annual increment for Norwegian aspen is 5.6 on site II and 5.1 on site III. The diameter range is covered in 25 years on site II and 30 years on site III (See Appendix VII.). Thus,in comparison with the Norwegian aspen on medium-good and medium-poor sites, the Scottish aspen has a poorer annual production. If grown on better sites the British aspen can be expected to produce a little more, but even so, the height growth

will probably not reach that obtained on the Norwegian site III and the production will still be correspondingly lower.

Comparison of the production on Norwegian sites II and III shows that on the poorer site it takes longer to produce less. It is not possible to deduce from this that the smaller British production (4.2%) is produced in a greater period of time than 30 years (Norwegian site III), as previously it has been shown (Figure 7) that the diameter growth of British aspen and Norwegian aspen on site III is approximately equal. Hence, the length of time which it takes the trees to pass from 5 inches to 11 inches in diameter will be approximately the same. The very limited number of ring counts that have been made in Scotland verify this approximately, the length of time being slightly longer than 30 years. It is therefore estimated that the length of time which it takes for the British trees to pass from 5 inches to 11 inches in diameter is between 30 and 35 years.

As an indication of the production of aspen in Britain, the production of the stand from which the above data has largely been obtained is now given.

The stand, composed of 102 live aspen trees of various sizes, and a large number of birch, covers an area of 2.4 acres. The aspen occur in small groups, scattered over the area. The number of trees in the groups varies between 3 and 15. The total volume present before the growing season in 1957 was, according to the local volume table (Appendix III) 770 Hoppus feet. The average volume per tree is 7.55 Hoppus feet. With an annual volume increment of 4.2% the stand will put on a volume of 32 Hoppus feet in one year. Thus by the spring of 1958 the stand

volume will have risen to 802 Hoppus feet.

The typical sporadic occurrence of the aspen makes it difficult to obtain any broad details of the aspen growth in Britain, but the growth in the Grantown-on-Spey area is typical of the Scottish aspen as a whole. Therefore, the above data can be considered to be fairly representative in Scotland. Further south, the growth is, in the main, poorer and little utilizable timber is produced.

4. THE USE OF ASPEN IN SILVICULTURAL PRACTICE IN BRITAIN

A. The Use of Natural Aspen Growth.

As far as can be ascertained natural aspen growth has not been treated in more than one area in Britain in the last 50 years. No doubt some aspen occurring as a component species in mixed woodland has received a certain amount of treatment along with the rest of the woodland, but pure blocks of aspen have been left to themselves. It is largely because of this that the stands of aspen are of such a poor nature, and in such a broken and rotten state.

In 1935 de Lotbiniere published an article (24) in which he described a growth of natural aspen which had occurred on his property at Brandon in Suffolk, and which he was treating. This natural growth of aspen apparently originated from one very large aspen which grew near the edge of a 40 acre mixed wood. This wood was cut down during the 1914-1918 war. In 1922 there were just a few aspen trees in a small group; in 1935 sucker regeneration covered an acre of ground. Since then it has continued to spread and has become a nuisance. The soil is sand over a chalk subsoil, but it retains moisture well and has a very good humus layer.

In 1935 the main section of the stand was 18 years old and had the appearance of a regular plantation, as it had been thinned in a regular manner, and the forest floor was clean. The trees had an average diameter at breast height of 4 inches and a height of 30 feet. The thinnings were carried out

Photograph 56. Part of a stand of 40-year old treated aspen. The form and growth are quite good and the crowns are healthy. The thick grass vegetation is clearly visible. Brandon, Suffolk.

Photograph 57. In another part of the same stand of aspen. Numerous aspen suckers are present and these indicate that light conditions on the forest floor are good. Brandon, Suffolk.

with the object of allowing the best trees ample space to develop their crowns to their full extent. Such thinnings have been carried out up to the present time. The trees are now between 45 and 55 feet in height and have an average diameter of 7 inches. For a time, a sample plot was laid out in the stand and measurements made annually, but this was given up after a few years and the records are now unavailable. The owner states that during this period, which was around the twentieth year, an average yearly diameter increment of a quarter of an inch was obtained. This is borne out by measurements of the ring widths in borespills. These indicate that in the first 20 years of growth there were 8-10 rings to the inch, whilst in the latter 20 years there were 12-16 rings to the inch.

The state of the stand at present is shown in Photographs 56, 57, 58 and 59. As already stated, the site is moist. It bears a thick ground vegetation mainly of Aira caespitosa but with occasional other grass species such as the Brachypodium spp., and Arrhenatherum avenaceum. Broom, Cytisus scoparius is common as is also the ivy, Hedera helix which can be seen growing on many of the tree stems. This vegetation has come in during the last 20 years as in 1935 there was no ground vegetation. This is because the thinnings which have been carried out, allow a greater light intensity to reach the soil. The presence of numerous aspen suckers is also indicative of this. Oak (Quercus pedunculata) has found entry possible beneath the light aspen crowns and is an indication of the probable natural evolution, the aspen being the forerunner of an oak forest.

The nature of the stand is clearly superior

Photograph 58. In the same stand of aspen. Here oak (right) has become established naturally under the aspen and this indicates the probable trend in the natural evolution. Ivy (Hedera helix) here causes some damage to the aspen. Brandon, Suffolk.

Photograph 59. Another view of the treated aspen stand. Brandon, Suffolk.

to the natural untreated aspen shown in the photographs in the previous section. The trees appear to be in better health, the bark is smooth and clear. Whilst the form of the trees is not very good it is better than in untreated areas. The height growth (45-55 feet in 40 years) is very much better than that normally found in Britain, especially as there is every indication that reasonable growth in height will continue for several years. This is because the crowns are still vigorous and show no signs of bushyness or heavyness. The diameter growth is also reasonably good. Very little rot has been found.

The trees now stand at an average spacement of 15 feet and there are approximately 190 trees per acre which is rather less than is customary in Norwegian treated stands at a comparable age. (See Appendix VII).

On the left-hand side of Photograph 58 there is a specimen of X P.serotina (furrowed bark). Several trees of this hybrid were planted amongst the aspen in 1934. The rapid growth, compared with that of aspen, is remarkable.

The treatment of aspen is clearly beneficial, for very much better growth has been obtained than is found in untreated stands. In addition, all the thinnings carried out have provided the owner with useful material for stakes, tool handles and horizontal rails for fencing. Treatment by thinnings is, therefore, not uneconomical and even in the early stages no financial loss was involved.

B. The Use of Aspen Growth of Artificial Origin.

As far as can be ascertained aspen has, up to the present, been used in plantations in only two areas. One of these is on the Castle Milk and Corrie Estates near Lockerbie in Dumfriesshire where in October 1956, 1,000 hybrid aspen, propagated by the Frølich's Foundation at Vollebekk in Norway, were planted. These aspen are of five different crossings: -

1.	P. tremula (Bamble, Telemark in Norway)	X P.tremula (Ås, Akershus in Norway)
2.	P.tremula (Morskogen, Akershus in Norway)	X P.tremuloides (Maple, Ontario in Canada)
3.	P.tremula (Våler, Østfold in Norway	X P.tremuloides (Maple, Ontario in Canada)
4.	P.tremula (Ås, Akershus in Norway)	X P.tremuloides (Maple, Ontario in Canada)
5.	P.tremula (Ås, Akershus in Norway)	X P.tremuloides (Maple, Ontario in Canada)

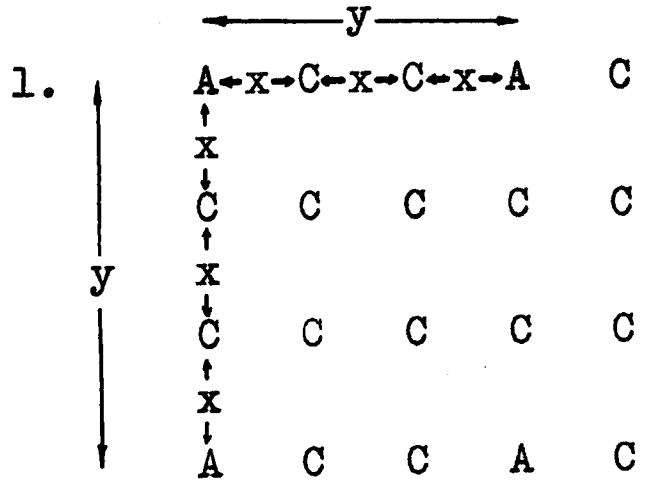
It will be extremely interesting to see how these different hybrids grow in this country. At present it is too early to obtain any information on this point. The plantation has been made on a flat riverside area which should prove suitable for the species.

The other area where plantations have been made is in the Ballochyle Estate which is owned by

the well known match manufacturing firm of Bryant & May Ltd. This estate is situated near Sandbank, Dunoon in Argyll. Here conifer plantations were commenced in 1922. In 1925 interplanting with aspen commenced with 17,000 plants planted at 12 feet x 12 feet, or 302 plants per acre. In later plantings the planting distance varied between 12 and 15 feet depending on the accepted planting distances for the conifer species in the mixture. Normally, every third plant within every third row, or every fourth plant within every fourth row, was aspen. This arrangement is shown in the following diagrams where A represents an aspen and C a conifer: -

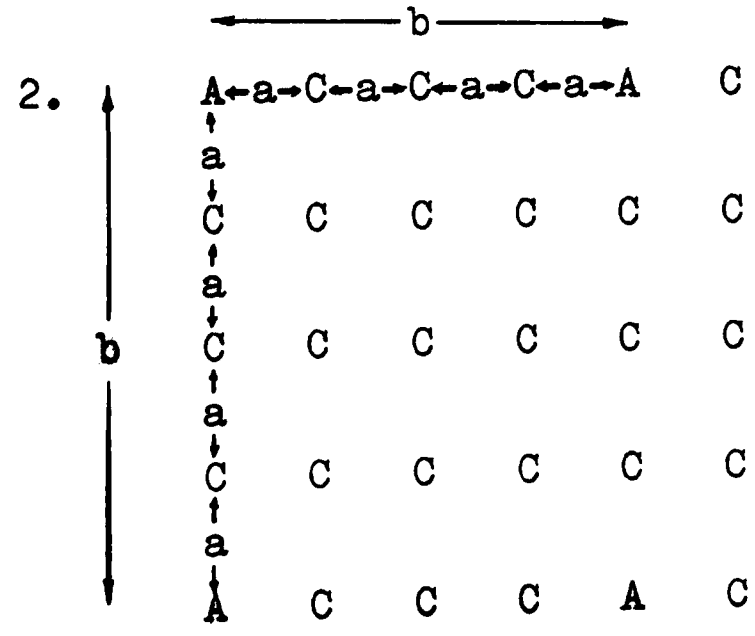
Figure 8. Diagrams showing the method used in planting aspen in mixture with conifers at Ballochyle.

1.



Where x = 4', 4:6" or 5'
and y = 12', 13'6" or 15'

2.



Where a = 3' or 3'6"
and b = 12' or 14'

The conifers used in the mixed plantations were Norway spruce (Picea excelsa), Sitka spruce (Picea sitchensis), European larch (Larix decidua), Japanese larch, (Larix leptolepis), Giant Silver fir (Abies grandis) Douglas fir (Pseudotsuga taxifolia), Western Hemlock (Tsuga heterophylla) and some Weymouth pine (Pinus strobus).

In the earlier plantings the conifers were put in two years ahead of the aspen on the premise that the aspen would outgrow the conifers. The objects of management were to grow aspen to match timber size on a 30 to 35 years rotation in mixture with spruce or other conifers as a secondary crop. This method was adopted by the firm to avoid the risk of putting all their eggs in one basket - in the event of failure by the aspen the spruce or other conifers would still be present and would then form the main crop. In most cases this has occurred as, speaking generally, in a well stocked plantation, the conifers outgrew and suppressed the aspen, although there is a scattering of aspen throughout the coniferous forest.

The aspen in the plantations suffered much in its early life owing to damage due to voles, rabbits, hares, and deer. This involved beeting-up the aspen to a large extent, which meant that the conifers had several years advanced growth, up to 15 feet, on the beeten-up aspen plants. For aspen, being a light demanding species, this was not a good position, and although attempts were made to save them by removal of the dominating conifer trees, the conifers would not be held back and sufficient light could not be made available to the aspen. The overall result was that the aspen were weakened and were unable to obtain

a sufficiently good start and the great majority succumbed for lack of light or to disease or to the effects of both.

Plantations were also made in which both the conifers and aspen were planted at the same time and a few with the aspen planted one or two years before the conifers, but in these, most of the aspen have also disappeared.

Plantations in which there are still a fair number of aspen are plantations in which both species in the mixture were planted together.

Most of the successes occur in the alluvial soil of the Strath bottoms; on the hillsides there are very few aspen surviving. It is noticeable also that the aspen grows better near the edges of the conifer plantations where there are better light conditions. The incidence of disease is apparent on many of the surviving aspen.

The condition and growth of the aspen in some of the plantations will now be considered:-

In the dense spruce stands occasional aspen have survived and where they occur they are usually up with the spruce, but are rarely over the spruce. The spruce, however, have not yet reached their maximum size and further growth will probably tend to suppress the aspen that have survived up until now. In most cases the aspen have been fairly well pruned by natural means.

A typical example of the growth of the surviving aspen in spruce is that in Compartments 14 and 15. Here aspen was planted together with sitka spruce in 1928. The latter at 4'6" spacings and the former at 13'6" spacings. In 1940 and 1942 thinnings termed

Photograph 60. A dead aspen tree. This tree has been overtopped by the sitka spruce. The bushy, somewhat heavy nature of the branches should be noted. Ballochyle, Argyll.

Photograph 61. Aspen showing good growth and form at the edge of a stand of sitka spruce and Weymouth pine. Ballochyle, Argyll.

"aspen release thinnings" were carried out with a view to improving the growth conditions of the aspen by the removal of many of the dominating spruce trees. The aspen are still up with the spruce in most cases, but only just, and it is likely that in a few years they will succumb as has the tree shown in Photograph 60. This tree has taller sitka spruce in close proximity on three sides. The heavy crown depicted here is typical. Most of the aspen trees have up to 20 feet clear of branches and the quarter girths vary between 4½ inches and 8½ inches. The heights naturally vary with the size of the spruce, but in general, trees of 4½ inches Q.G. are about 40 feet tall and trees of 8½ inches are 60 feet tall.

Photograph 61 shows aspen growth in a stand of sitka spruce and Weymouth pine. The central aspen tree is situated on the edge of the plantation. It has a quarter girth at breast height of 6¼ inches and a top height of 54 feet. In this plantation (Compartment I 1C.) the aspen and conifers were planted together in 1929, and hence are now 28 years old. The average size of the aspen here (11 samples) is 48.5 feet in height and a quarter girth at breast height of 5¾ inches (or 7¼ inches diameter). If these figures are plotted on the graph, in Figure 7, it can be seen that this growth is superior to that of aspen of the same age on the Norwegian sites II and III. But these figures represent extremely forced growth and there is little likelihood of further height growth as the trees will soon be overtopped by the spruce and pine. However, these figures show that a good rate of growth can be obtained in Britain, but even so, none of the trees are of sufficient size to

fulfil the specifications of the British match industry.

It is rather strange, but the best aspen growth on the estate occurs in Compartment 13A which is composed of tsuga and aspen. As the tsuga is so heavily foliaged it would be thought that the aspen would have insufficient light. These species were planted together in 1927 at a spacing of 4'6" and 13'6" respectively. The average height of the stand is 55 feet and the few aspen that still remain are extremely well formed and the crowns are still fairly healthy. The base and extensive roots of the best aspen tree in the stand are shown in Photograph 62. This tree has a height of 56 feet and a quarter girth at breast height of $8\frac{3}{4}$ inches (or $10\frac{1}{2}$ inches diameter) at 30 years of age which again is superior to the average Norwegian growth.

Aspen has largely failed in mixture with the larches which outgrew it and in general most of the aspen occurs amongst the spruces. Everywhere, near any aspen, suckers occur abundantly wherever there is sufficient light. But under the stands the suckers, although they occur, never reach more than 6 inches in height before they succumb because of lack of light. In no places are aspen suckers present which are more than two feet high.

The policy at present is to treat the stands as conifer stands, but if good, healthy aspen occur they will be retained if the condition of the surrounding conifer stand is suitable. Any aspen which is cut out in the course of the normal thinnings of the conifers is cut, like the conifers at present, into pit prop lengths and sold as same.

In the future, aspen will not be utilized in plantings as sufficiently good and healthy trees have

not been grown in the required rotations. It is evident that the rotations chosen are very short and are only half of those normally in use in aspen stands in Norway where spruce and aspen grow extremely well together. But in Norway the aspen only exceptionally occur as single trees amongst the spruce. Usually small groups grow up together and by this means very much more favourable growth conditions are obtained. The necessarily larger gaps in the spruce stand let in more light to the aspen, which can be treated more or less as a separate entity, but the benefits of the mixture are not lost. The benefits can be enumerated as follows: - Greater stability in the stand because of more varied root systems and crown types. The uniform spruce heavy canopy is broken by the light aspen crowns occurring amongst it. There is less risk of fungal or insect damage of an epidemic nature to either species. The mixture of species means that a mixture of litters is obtained and this has a favourable influence on the break-down process and on the soil conditions.

It is quite probable that groups of aspen planted amongst the conifers instead of a stem-wise mixture would have produced more favourable results. At any rate, less suppression would have been experienced by the aspen and should beeting-up have been necessary the beeten-up plants would have had a better chance of survival. The growth of the aspen which were able to keep their heads above the conifers clearly shows that reasonable growth is possible. A group-wise mixture would have allowed such growth to occur and also would have permitted more to occur. In any future plantings in mixture the aspen should be tried in groups.

At Ballochyle the strains of aspen used are mostly of Polish origin, but have not shown very good form as is indicated in Photograph 63, where the extremely bushy type of crowns can be seen. More research into the most

Photograph 63. A plantation of Polish aspen at Ballochyle. The poor form and growth and especially the bushy crowns are visible.

suitable strains or hybrids must undoubtedly be carried out before further plantations are formed.

In the future, at Ballochyle, the question of sucker regeneration may become real. This is because the conifer plantations with their occasional aspen will be clear-cut. Widespread sucker regeneration of aspen will undoubtedly occur unless all the aspen is removed several years before the conifers. The owners do not wish to obtain sucker regeneration as they wish to continue with conifer plantations but it may be wise to utilize some aspen sucker regeneration in groups about the forest as more suitable results might be forthcoming. Sucker regeneration may be so dense and vigorous that further conifer plantations will be impossible, at least until the aspen is quite old when conifers can be introduced beneath it. This question will not, however, be met with until several years hence and the policy of the owners may have changed by then.

In addition to the aspen plantings in mixture with conifers a small area of Compartment 14 in Section II was planted with pure aspen of three different races. There is no record of the planting date and the experiment has not been kept up. Each tree was originally supplied with a tag bearing its origin, but most of these have now disappeared and the boundaries between the races are not defined and hence the purpose of the experiment - to determine which race or provenance showed the best growth, has been defeated. However, some indication of the different growths can be obtained. Most of the area is planted at a spacing of 9 feet x 12 feet with a Polish strain of aspen similar to that used over most of the mixed plantation area. Part of the pure plantation showing the Polish aspen is shown in Photogrpah 63. As can be seen the form

is not good, the crowns being heavy, long, and are inclined to bushyness. The stems show several signs of ill health; they are lichen covered, some trees are completely dead and removal of the bark shows a mass of dark brown rhizomorphs of Armillaria mellea; many of the branches are dead or broken. The best stem of the Polish strain and of the whole plantation is not shown in the photograph. It has excellent form, with a straight and regular stem. The top height is 58 feet and the quarter girth at breast height is 7¾ inches. The first live branch occurs at 20 feet, but some dead ones are retained below this.

A few aspen of Russian origin occur in one corner and are showing reasonable growth, but are being hampered by neighbouring spruce.

Some Populus tremuloides of Canadian origin occur in mixture with the Polish race in another corner, but are not doing very well.

This single trial, the records of which have not been kept up, is little indication of the growth of aspen of foreign races in Britain, but in general the height growth is superior to that of the native aspen (although none occur in the same area under the same conditions). The rainfall at Ballochyle (70 - 80 inches/annum) is perhaps somewhat excessive for aspen, but most of the conifer species used thrive extremely well.

From this very limited amount of aspen growth of artificial origin it is difficult to draw any conclusions for the whole of Britain, or even Scotland. Very much more research is required in this sphere in Britain if aspen is to become an economically valuable tree.

C. The Artificial Reproduction Methods Used in Britain.

In Britain small scale nursery trials with aspen were carried out at the Kennington Nursery, Oxford, between 1934 and 1949 (Gray 15). The results of these experiments show that aspen can be grown successfully in the nursery and the following is an account of the findings there.

The catkins are collected when the pappus becomes visible and spread out under cover, with some protection from strong winds, until the seed is dehisced; this usually happens in about two days. It was first thought necessary to separate the seed from the pappus prior to sowing, in order that the seed may make contact with the soil, and not be blown away by the wind. More recent investigations, however, reveal that this separation is not necessary, and that the pappus assists in sheltering the minute seedling during and immediately after germination. It is advisable to sow the seed as soon as it emerges from the catkins so as to obtain maximum germination.

The seed-bed should be firm and absorbent (because of the intensive watering required). The surface layer of the bed should be very fine in texture. A suitable medium can be prepared by mixing riddled broad-leaved humus with the nursery soil, and finally preparing the surface with a layer of dry nursery soil passed through a fine-meshed culinary sieve.

The seed should be broadcast thinly and lightly, pressed into the soil, but not covered. Watering is necessary until the seedlings are established. This should be light and frequent, ensuring that the surface soil remains permanently moist. The seed-beds should be

shaded by means of laths or hessian, or a combination of both, against rain and all direct sunlight, until the first true leaves appear, when the shade may gradually be reduced.

Germination usually begins about eighteen hours after sowing. Growth at Kennington has been found to be somewhat slow during the summer, but to become active during early autumn, and seedlings may attain a height of eight or nine inches in their first year.

The seedlings should be lined out at the end of the first year, in fertile soil at a spacing of not less than four inches within, and twelve inches between, the rows. After transplanting, growth is frequently disappointing, as most plants develop a drooping habit of growth. Cutting back the shoot to within one inch of the root collar, after the first year's growth in the lines has been found to be effective in producing straight shoots on the majority of the plants.

The "cut-back" one-plus-one transplants should be re-lined in manured ground at a spacing of two feet within, and from two-and-a-half to three feet between the rows; these distances permit of mechanical cultivation of the ground. Subsequent growths should be reduced, when approximately six inches in height to a single shoot per plant, leaving the best-placed shoot to form the leader. The plants should normally be ready for planting in the forest one year after cutting back (i.e. one-plus-one-plus-one stock).

Transplants aged one-plus-one normally average two feet in height, and re-lined transplants at the one-plus-one-plus-one stage, fit for forest planting may reach a height of six feet.

In the Norwegian nursery practice referred to in Part III no cutting back is necessary as the plants produced are upright and do not develop a drooping habit

of growth. This indicates that, even in the early stages of growth native British aspen is inferior to Norwegian aspen. This is also brought out by the differences in height growth in the first year, although this could be attributable to the different methods employed. In the first year, on the average, the Norwegian aspen reach a height of three feet, which is very much better than the nine inches obtained at Kennington. The second year's growth is normally up to six or seven feet and again is vastly superior to the English aspen's growth.

The Norwegian aspen is ready for forest planting in one or two years compared with the three years necessary for the English aspen.

[* Börset (1960) actually states that 1 year seedlings in Norway grow to 20 - 30 cm (8 - 12") , and exceptionally to 50 cm.. In their 2nd year they grow to 1 - 1.5 m. Norwegian plants are also stumped back & sold as 1 + 1s

Rick Worrell 1993]

PART III.

A STUDY OF THE CONDITIONS OF ASPEN GROWTH IN NORWAY, WHERE THE TREE IS TREATED AS ECONOMICALLY VALUABLE.

1. THE SILVICULTURE AND UTILIZATION OF ASPEN IN NORWAY.

(A). The Silviculture of Aspen in Norway.

The forests of Norway, which are among the most northerly in the world, cover some 18,520,000 acres, or just under a quarter of the total land area. About 3,457,000 acres of this forest land are covered by polar birch forests and birch forests lying above the coniferous limit. Productive forests, in the ordinary sense of the term, constitute about 15,063,000 acres.

About 30 percent of this total productive forest area is covered by deciduous forests. The most valuable leaf-trees are found in South Norway, which partly belongs to the region of summer-green broadleaved species, generally termed the deciduous forest region.

According to the latest surveys, the total growing stock in the Norwegian forests is estimated at about 11,470 million cu. ft. and the annual increment amounts to about 450 million cu. ft. Of this annual increment about 71 million cu. ft. or approximately 16%, represents leaf-tree timber, the remainder being spruce and pine.

The leaf-tree forests are composed, primarily, of birch, aspen and oak; other species occurring in small numbers only.

In the latest forest survey, the total volume of aspen was estimated at 191 million cu. ft. and the annual

Photograph 64. Typical Norwegian aspen. The good form is quite evident. Telemark.

production about 8 million cu.ft. The total volume of aspen amounts to about 12.5% of all leaf-trees and 1.7% of all trees (both leaf-trees and conifers)

Thus, in Norway, as far as volume of timber is concerned, the aspen is an important constituent of the leaf-tree forest, and of late has become, in certain districts, the most important leaf-tree species. Typical Norwegian aspen is shown in Photograph 64. Although aspen is to be found in nearly every part of Norway, the principal area for aspen is Southern Norway and particularly the counties of Vestfold, Telemark, Aust-Agder and Vest-Agder.

According to the latest survey the details for aspen in these four counties is as follows:

TABLE 11. The distribution of aspen over some Norwegian counties.

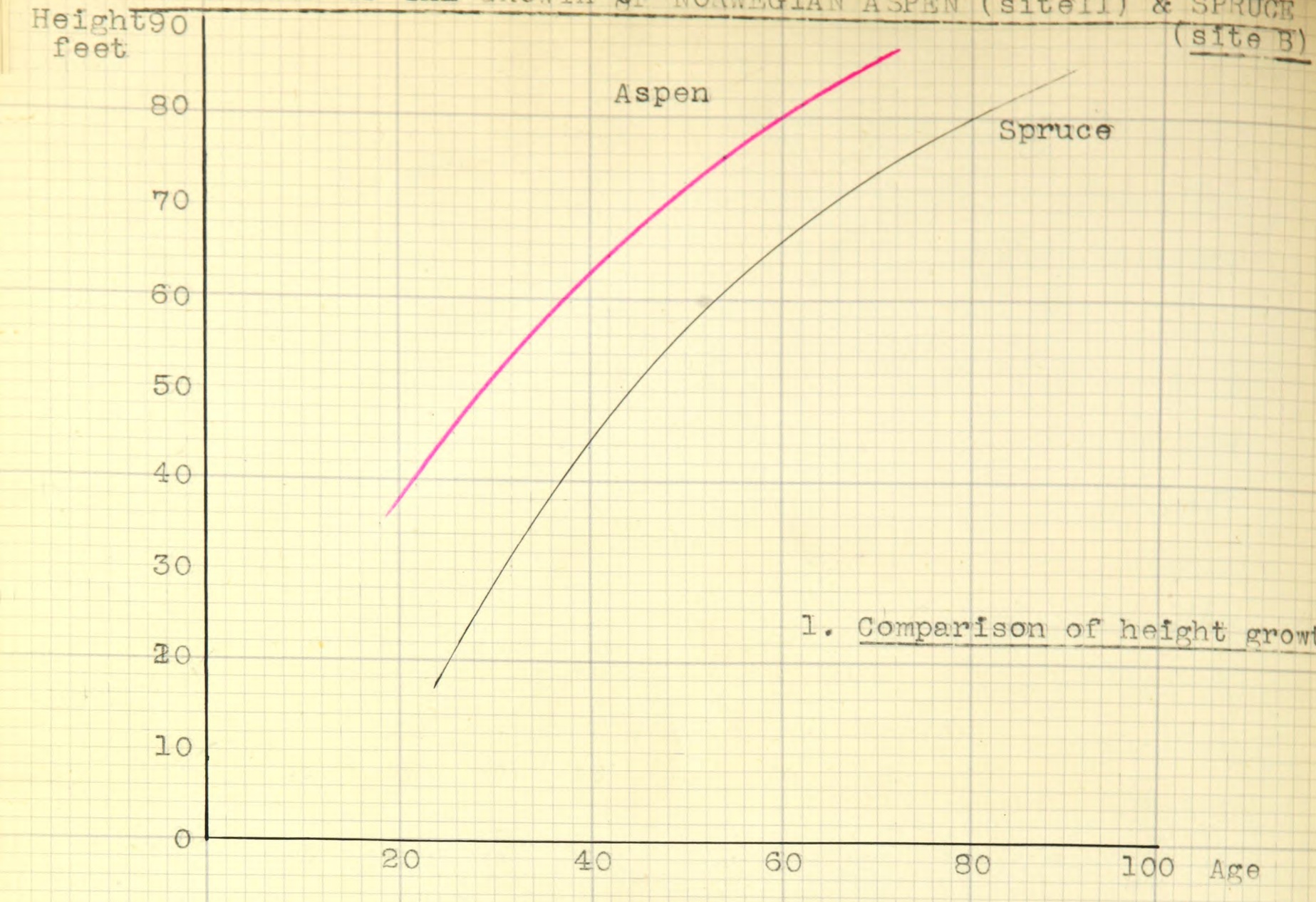
County	Total Volume of aspen.c.ft.	Annual Prod: of aspen. cu.ft.	Percent-age of leaf-trees	%age of all trees.
Vestfold	13,620,000	674,200	19.7	3.4
Telemark	40,920,000	1,678,000	23.0	3.1
Aust-Agder	45,120,000	1,895,000	29.3	6.1
Vest-Agder	24,570,000	1,030,000	19.4	6.7

In the counties of Buskerud, Hedmark, Akershus and Østfold aspen is also of some importance, but in these areas the tree is not so numerous nor of such good form and growth as in Southern Norway.

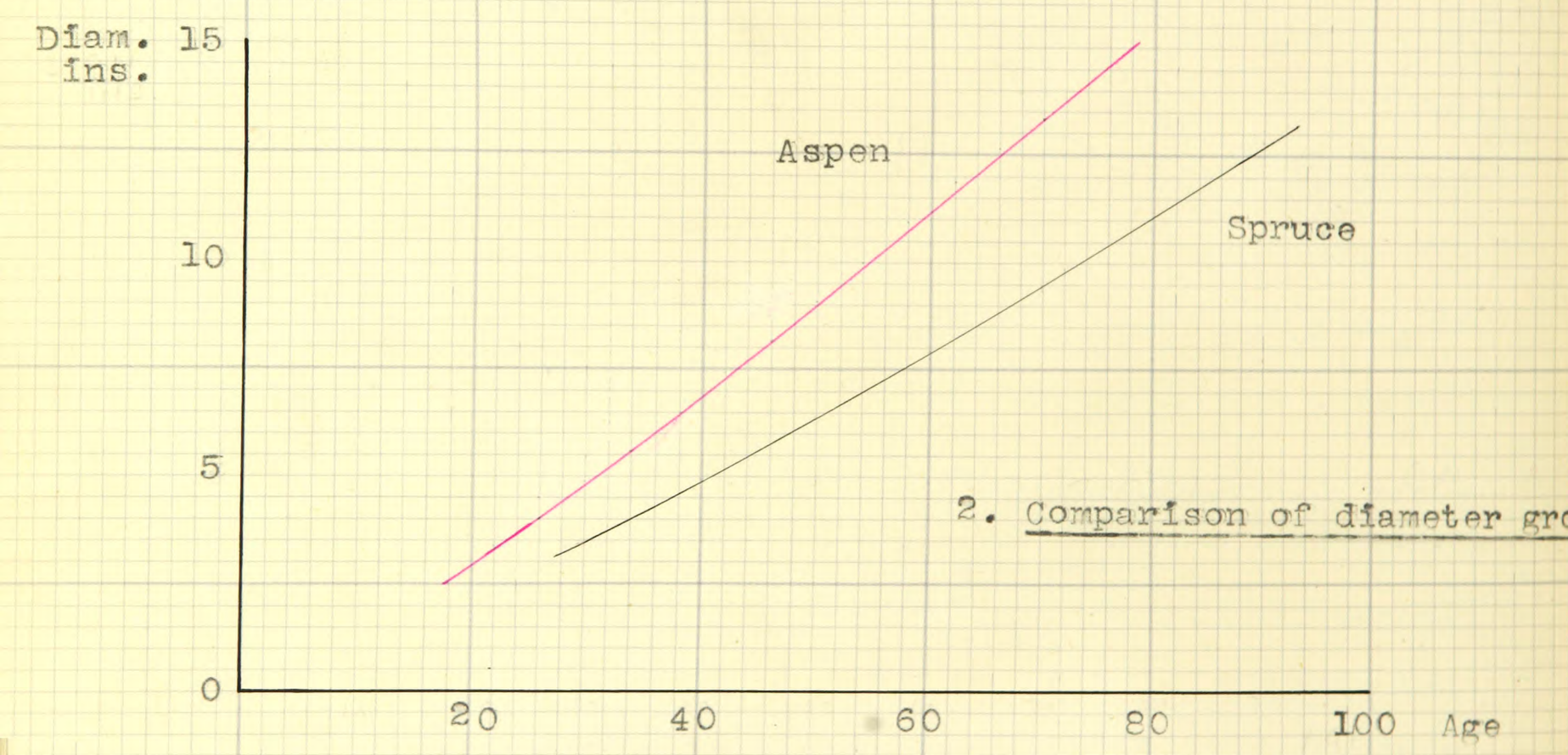
In Norway investigations into aspen growth are carried out primarily by the Ingeniør F.H. Frølich's Foundation, and to a lesser extent by the Norwegian Forest Research Institute. These two organisations have laid out a number of sample plots, the positions of which are shown on the map (Appendix V.). The positions of the plots

FIGURE 9

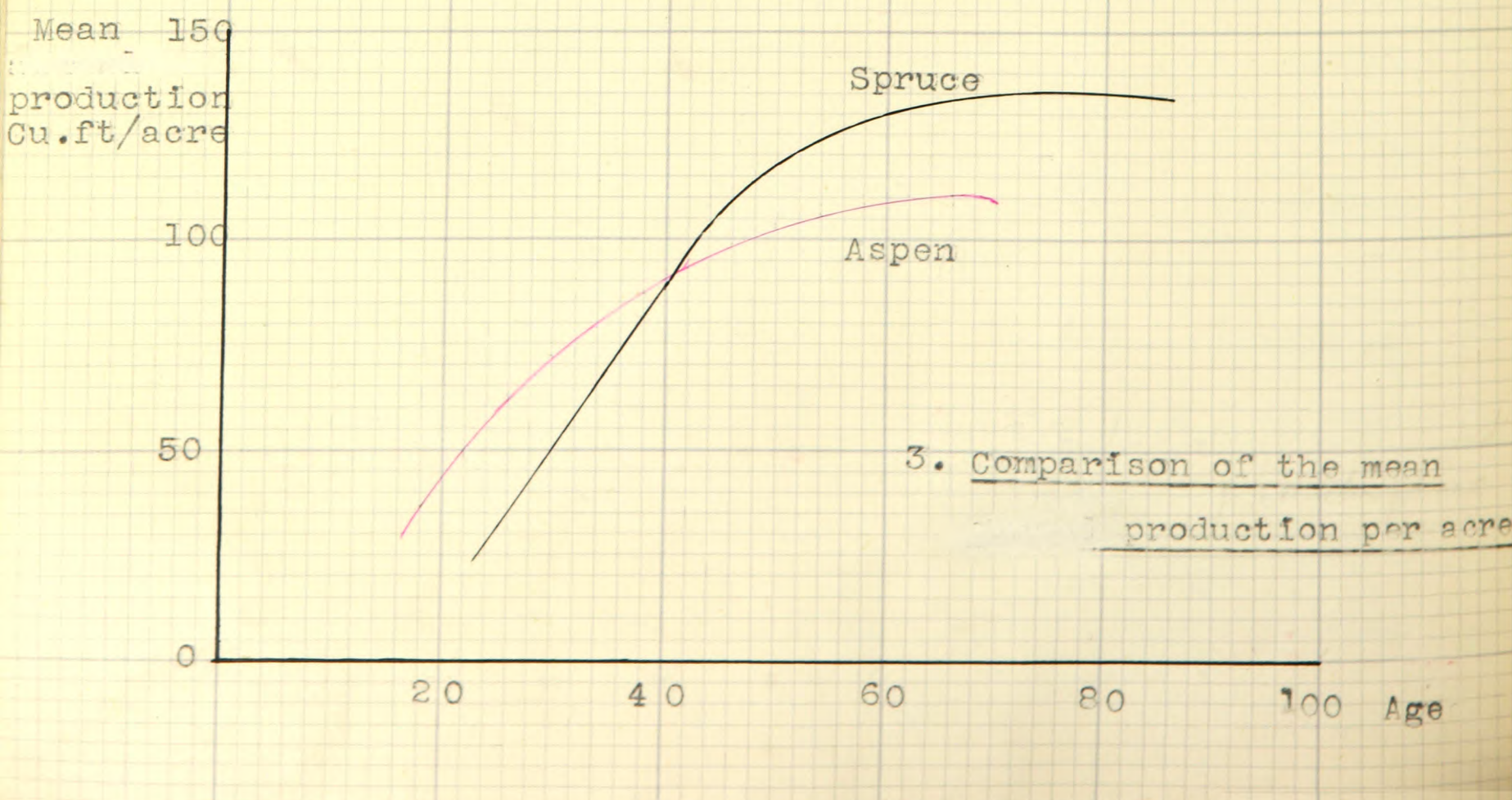
COMPARISON OF THE GROWTH OF NORWEGIAN ASPEN (site II) & SPRUCE (site B)



1. Comparison of height growth



2. Comparison of diameter growth



3. Comparison of the mean production per acre

have few disadvantages and many advantages, but if seedlings occur they are utilized.

Having dealt with the general position of aspen in Norwegian forestry, the sites it occurs on, its ecology and regeneration, the growth and yield of aspen will now be considered.

Over the last 13 years data has been collected from sample plots by the Frølich's Foundation and also by the Norwegian Forest Research Institute. From a study of these data a great deal of information regarding the growth of aspen in Norway can be obtained. Some details of the sample plots and a summary of the data is given in Appendix VI. The plots, whilst mostly comprising aspen of middle age, covers all ages, In most, measurements started some five to ten years before those given.

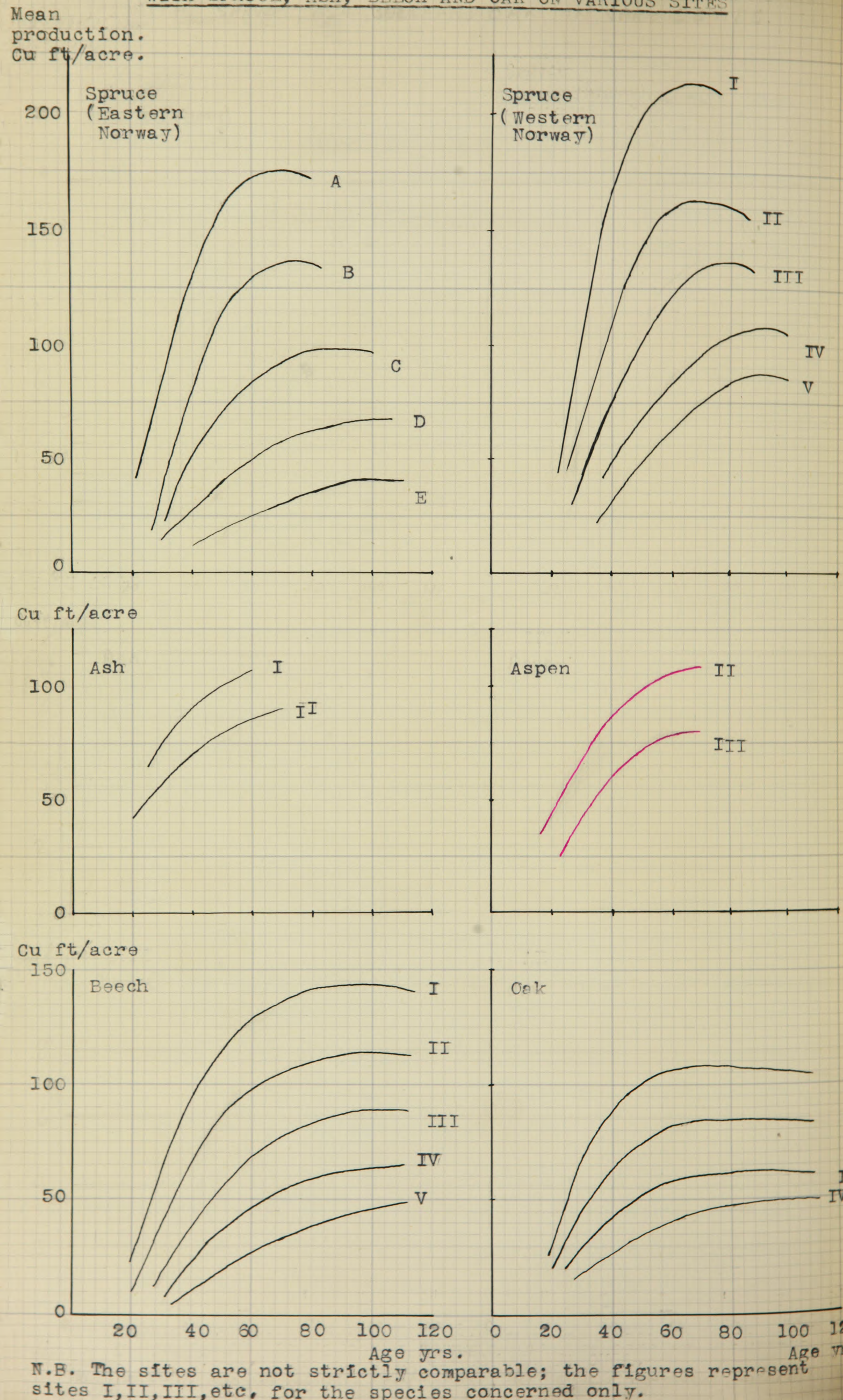
From the data obtained from the sample plots yield tables for aspen on both good and medium to poor sites have been derived. These tables appear in Appendix VII. From them average growth curves can be drawn and these serve as a basis of comparison of aspen growth with that of other species.

Figure 9 (1) shows the height growth of aspen on aspen site II in comparison with spruce on spruce site B. Although these sites are not the same, the conditions are comparable. The curves show that aspen has a larger growth rate than spruce in youth and that in height a rotation of about 70 years for aspen is equivalent to 90 years for spruce on these sites.

Figure 9 (2) shows a similar comparison for mean diameter growth. In this, thinnings play an important part and the aspen has been thinned lightly from the start. Aspen diameter growth is greater than that of spruce on these sites and the aspen reaches a greater diameter in

FIGURE 10

GRAPHS SHOWING COMPARISON OF THE PRODUCTION OF ASPEN WITH SPRUCE, ASH, BEECH AND OAK ON VARIOUS SITES



N.B. The sites are not strictly comparable; the figures represent sites I, II, III, etc, for the species concerned only.

70 years than the spruce does in 90 years.

A comparison of the average volume increment of aspen and spruce on comparable sites is shown in Figure 9 (3). These curves show that aspen has a higher volume increment in its youth, but the spruce surpasses it in later life. The aspen has a maximum mean production of 120 cu. feet per acre at about 65 years, and the spruce a maximum mean production of 135 cu. feet per acre at about 75 years.

On the best aspen sites it is expected that a mean production of 140 cu. feet per acre could be achieved.

A comparison of aspen production with spruce, and some leaf-tree species is given in Figure 10., from which it is clear that aspen can be grown to timber sizes on a relatively short rotation in Norway.

The data obtained from the sample plots made in aspen have been utilized by the Frølich's Foundation to construct a volume table for aspen. Trees felled in the course of thinnings in the plots have been cut into one or two metre sections in order that their volume could be obtained. Altogether 1,262 trees were measured. The Norwegian aspen has been found to have a form factor of 0.5.

The volume table has been tested in various ways and has proved most satisfactory, even with the Estonian giant dimension aspen described by Mathiesen (26)

The volume table is included in Appendix VII, and may prove of use in Britain in the future although it is not applicable for most of the British aspen at present as they fall short in height.

As can be gathered from the amount of data that has been collected the aspen is a major economic species in Norway. Its growth is very good on the sites that suit it and the form of the stems is, as a rule, very fine.

Photograph 80. A mixed, fairly open stand of aspen and birch. This formed the initial tree vegetation after a fire in 1897. Now, spruce is entering the stand - indicating the natural succession. Haugsjå, Aust-Agder.

Photograph 81. A fine group of aspen trees. Near Holt, Aust-Agder.

Photograph 82. Well grown aspen trees near Austre Moland, Telemark.

Further examples of this are shown in Photographs 80,81, and 82, whilst Photograph 83 shows a view looking up the stem of a large 75 year old aspen at Idd in Østfold. The fairly regular and symmetrical crown should be noted.

Two excellent stems are shown in Photograph 84. These trees are about 100 feet tall and have quarter girths at breast height of 13⅞ and 13 inches. The boles are round and are almost cylindrical. The bark is fine and clean and there are no signs of ill health. Originally these stems formed part of a group of aspen in a stand of spruce. The spruce was cut in 1955.

The form and growth of aspen in Norway is not everywhere similar, but generally speaking it is very much superior to that in Britain. The primary diseases of British aspen also attack Norwegian aspen, but nowhere are there such obvious signs of ill health. Only occasional trees show outward visible signs of rot in the form of fructifications. The crowns are normally well formed, vigorous and free from any extensive breakage. Bacterial canker does occur in Norwegian aspen, but it is not at all common. A few cankered specimens occur near Haugsjå in Froland and one of these is shown in Photograph 85. The fact that outward signs of ill health are few does not mean to say that rot of the timber does not occur much. Heart rot does occur extensively but it does not often render the trees useless. The incidence of rot is naturally higher, the less suitable is the site. In the counties of Aust-Agder, Telemark and Vestfold the incidence of rot is at a minimum, but there is more in Vest-Agder and the more northern counties. A lot of damage seems to be caused by extraction work as the bark and branches are relatively tender and easily damaged.

Nevertheless aspen is a valuable tree and its silviculture is a most important feature of forestry in

Photograph 83. A view looking up the stem of a large 75-year old aspen tree.
Idd, Østfold.

Photograph 84. Two excellent aspen stems.
Tvedestrand, Telemark.

Photograph 85. Bacterial canker on aspen at Haugsjå, Aust-Agder.

Southern Norway. The culture of the aspen is also important from economic and aesthetic viewpoints. It is the most important leaf tree species in Southern Norway.

Photograph 86. Some fine match-timber. These logs are the first and second logs of a single 50-year old tree. A third log is also of match-timber size. The tree grew on an exceptionally good micro-site. Haugsjå, Aust-Agder.

(B). The Utilization of Aspen in Norway.

Aspen has been utilized in the match making industry in Norway for many years and this was, until recently the only outlet for aspen apart from firewood. As firewood, aspen is not very suitable as it burns rapidly and does not give out much heat, because of its relatively low density. For matches, a minimum size of timber with special rules concerning rot is required. All aspen which falls short of the standard set is rejected. It is largely because of this that there has been very little treatment of aspen until recently. If a forest owner happened to have aspen growing stock suitable for matches all well and good, but normally much of the aspen grown had to be wasted and in consequence it was a despised tree and not welcomed by most forest owners.

Now, however, the situation has happily altered and aspen has become the most important leaf-tree species in certain areas. This increase in popularity has been brought about by changes in the uses of the timber. The match trade is still the major outlet for large-size timber but now there is an outlet for the smaller-sized timbers and also, to some extent, for slightly rotted timber. Hence the growing of aspen is now economic as all sizes of timber can be readily disposed of. This is an extremely important factor in Norwegian forestry as now the aspen with its soil improving litter is welcomed in the forest as it increases the forests' value both monetarily and aesthetically. This latter is of considerable importance in Norway with its beautiful scenery.

In Norway, at the present time, there are four main uses of aspen timber. These are: - (a) Matches and matchboxes, (b) Veneers, (c) Pulp and paper and

Photograph 87. Stored aspen timber in the yard of the match factory at Stavern, Vestfold.

Photograph 88. A closer view of the stored match timber. Some slightly rotted timber has been accepted. The log top right shows tunnels of Saperda carcharias. The pipe and nozzle at the top of the photograph forms part of the spraying mechanism. Stavern, Vestfold.

Photograph 89. Small sized aspen billets for use in packing boxes or axles for rolls of paper. The billets, right centre have been cut in readiness for peeling. Stavern, Vestfold.

The annual amount of aspen cut for sale in Norway is about 60,000 cu.m., or 2,168,000 cu.ft. Of this figure between 30 and 35 percent is used by the match industry. the remainder being distributed between the other above-mentioned industries.

(a) The Match and Match-box Industry.

Match and Match-box making factories are situated near the major aspen growing regions. The factories accept all large-sized aspen timber provided it is not badly rotted or damaged in any other way. The precise specifications are given in Appendix IX., the minimum middle diameter accepted is 20 cm. (7.88 inches) and the minimum length 2 m. (6ft.6 ins.). Some fine match timber is shown in Photograph 86. The large log on the right is the butt-log of a 50 year old tree which has been grown extremely well. The second log of this tree is the one on the left. Both are 25 feet long. A third log (not shown in photo) is also of match timber size, but is rather branchy towards its top end.

The aspen timber is cut in winter and conveyed to the factories by road, rail or ship, and stored as shown in Photographs 87 and 88. Sufficient timber is stored for one year's production. While stacked the timber is sprayed both night and day by a special solution of 1% "Santobrite". This is a prevention against fungal attack. One of the spray pipes and a nozzle is shown at the top of Photograph 88. Small-size timber as in the right hand corner of Photograph 87 and in Photograph 89 is used for axles for rolling paper and for packing boxes for match boxes.

The details of the match-manufacturing process are given in Appendix VIII.

Photograph 90. Aspen timber showing varying amounts of rot. All but the most badly rotted logs, 1, 2. 3 and 4 will be acceptable for use in the wallboard industry. Haugsjå, Aust-Agder.

(b) Veneer and Plywood Industries.

A relatively small amount of aspen is used in the veneer and plywood industries. The specifications for the timber are again strict and the industries require a larger mimimum thickness than does the match-industry. Aspen for plywood obtains the same scale of prices as does birch for plywood.

The comparative specifications for veneer and match timber are given in Appendix IX.

(c) Pulp and Paper Industries.

It is essentially the fact that aspen is now utilized in these industries that has brought the species into favour as a timber producer. This is because the industry takes small sized logs such as those taken in thinnings of medium sized aspen. For pulp and paper the same price is given for aspen as for spruces. Aspen is chiefly used in the manufacture of absorbent types of paper such as blotting paper, tissue paper and the thick soft paper commonly used in childrens' books.

(d) The Wallboard Industry.

In this industry aspen is useful because of its low density when dry. It is used mainly in mixture with other species. A further advantage to the aspen growers is provided by this industry since timber, which has rot covering too large an area for match or veneer timber is often taken. Such timber is shown in Photograph 90. The most badly rotted timber cannot, however, be accepted.

Aspen when grown properly is as profitable as spruce and is easily the most economic leaf-tree species in the areas, where it grows best. This is because all sizes of timber can be sold. On the other hand, oak, for instance cannot be sold in small sizes and hence it is considered uneconomic to thin oak.

2. ARTIFICIAL REPRODUCTION AND TREATMENT OF ASPEN IN NORWAY.

Since natural reproduction by root suckers is extremely common and considered to be adequate in Norway, artificial reproduction is not resorted to very much. Most of the artificial regeneration of aspen, which is carried out in Norway, takes place in the nursery of the Frølich Foundation in Vollebekk in the county of Akershus. This is primarily connected with experimental work on the aspen, involving various crossings of different strains and species. The progeny of these crossings are later used in provenance trials, thinning trials, pruning trials and the like, but some plants are supplied to various parts of the country for general plantation work. 1,000 hybrid aspen plants were sent to an estate at Lockerbie in Scotland in 1956.

All artificial reproduction is carried out in a similar manner. In the nursery, there are graftings of many strains and species of aspen. These graftings are all carried out on common aspen stock. The species utilized are Populus tremula, P.tremuloides, P. grandidentata, P.deltoides and P. seyboldii. These graftings are made in order that seeds may be obtained from all these species, if desired. Normally, however, natural trees provide the necessary materials.

The grafted mother trees are cut back annually so as to prevent growth in height, and to facilitate the cutting of catkins when these are required.

Twigs, with unopened catkins are collected from the required mother trees in late February or early March. These twigs are placed in water in a greenhouse, in which, throughout the fertilization period, a temperature of about 25° C. is maintained. The water is changed daily in order

to maintain a suitable quantity of oxygen and to prevent infection by fungi.

After a few days the catkins open and when the red colouration of the stigma is clearly visible, the pollen is placed upon them. Both before and after pollination, the catkins are covered by plastic bags so as to ensure that pollination occurs only by means of the artificially introduced pollen. In this way the required crossings are ensured as both the female and the male parent can be selected at will. Crossings between different species and provenances is thus made extremely easy. The pollen is readily transportable and may be sent by air. In this manner a great many different crossings of different provenances of Populus tremula and P. tremuloides have been made in a very short space of time and under extremely easily controlled conditions.

The aspen is prone to both parthenocarpia and to attack of the seeds by the fungus Taphrina johansonii, and the insect Epiblema nicella. The former cannot be prevented and thus it occurs to some extent under controlled conditions. The latter may be curtailed if the catkins are sprayed with "Bladan" a few days after pollination. The female catkins just after pollination are shown in Photograph 13; a few capsules in this instance are enlarged owing to attack by Taphrina johansonii.

After two weeks the capsules ripen and open and the seed and its accompanying woolly pappus is released and hangs for a while about the catkins. This stage is shown in Photograph 14. Both the pappus and the seed are gathered together, and both are sown immediately in boxes.

If no control of pollination is required, aspen seed can be gathered by cutting small branches rich in catkins and about two feet in length from female trees.

As the time for seed-shedding approaches, it is necessary to follow the development of the catkins from day to day, so that they can be gathered at the time the seed capsules begin to open displaying the white pappus.

Investigations carried out by Reim (28) have shown that there are far more male trees than female trees and that the number of seeds contained in each capsule is dependent on the possibilities for pollination. When collecting seeds it is essential that both sexes of tree are present in the stand.

Naturally, when the seeds are collected from trees and not after artificial fertilization and tending, there is more likelihood of damage to the seeds by fungal and insect means. The cut branches are collected just prior to the dehiscence of the capsules and when this occurs all the seed and pappus can readily be collected. Subsequent to collection the seed from both sources is treated similarly.

The boxes utilized at Vollebekk are roughly one foot wide, two and a half feet long and three inches deep.

In the boxes there are three different layers. Firstly at the bottom there is a one-inch layer of coarse peat; secondly a one-inch layer of "Huminal" which is a turf-like substance prepared with artificial manure; and thirdly a half-inch layer of finely divided Sphagnum peat. This is well watered and the seeds, together with their pappus, are spread over the fine Sphagnum layer and are not covered. The layer of Sphagnum is free of organisms and thus weeds are not a problem.

Very nearly 100 percent germination is obtained, whereas in open natural conditions, perhaps one seed in a thousand germinates. Contrary to widespread belief, the germination power of aspen seed is thus fully as good as for seeds of other forest trees, under controlled

After two or three weeks the young seedlings are transplanted in order to give them greater space. Similar boxes to those used previously are filled with common soil; preferably soil which has been sterilized, and the transplanting is carried out, the young plants being placed at two or three inches distance.

The boxes of plants are retained in the glass-house until a week or two before the plants are to be planted out in the nursery transplant beds. The young aspen cannot be transplanted directly into the open and therefore the boxes are placed outside and shaded for a week or two. When the plants brown off they are considered hardy enough for planting out. Photograph 91 shows the boxes of aspen plants just prior to planting out.

In the transplant beds the aspen are placed at a distance of four to five inches , and if necessary they are watered in. Photographs 92 and 93 show respectively the aspen transplant beds at Vollebekk, and a vertical view of the plants in the bed three weeks after planting out.

The young aspen generally attain a height of between three and four feet in their first year, but if the summer is too dry and very hot the growth is somewhat retarded, and the young plants only attain a height of between one and a half and two and a half feet. Some one-year old aspen transplants are shown in Photograph 94. These are only about two and a half feet tall and reflect the somewhat dry nature of the previous summer (1956).

After a good first season, the one-year old plants can be planted straight out into the forest, but if the first season is poor the resultant small plants are best left for a second year in the nursery when their height will normally be between six and seven feet. No cutting

Photograph 93. Aspen plants in the transplant bed. The form of the first leaves should be noted. Vollebekk, Akershus.

Photograph 94. One year old transplants. Vollebekk, Akershus.

back, or pruning is carried out and the plants, as a rule, are straight and upright with only a few small side branches. This is due largely to the genetical make-up of the parent trees, as only trees of fine form and growth are utilized, whether they are Canadian, Norwegian or from any other area.

In the nursery, the main problem is that of weeds, the young aspen must be kept as free from weedgrowth as possible. Occasionally, extensive damage is done by leaf-eating and leaf-mining insects, but normally these insects cause insignificant damage.

The aspen plants are sometimes lifted from the nursery in the autumn of their second year and stored for planting out in the following spring. Storage is carried out underground. At Stavern an old air-raid shelter is utilized for this purpose. The plants are placed in the dark and the roots covered by soil. The temperature remains at 2 - 4^{o} C. during the winter and provided the humidity is not too great the plants will last well.

The first consideration when planting out the young aspen trees is that the site is a suitable one. Aspen requires a good soil which has a good supply of moving water, but it should not be a wet soil. The lower slopes of hills formed of rich rock are quite suitable as usually there is an accumulation of mineral matter, a reasonably deep soil and good moisture conditions. The flatter areas of the valleys would be extremely suitable, as a rule, but these areas are usually required for agriculture.

As stated previously, one-year old plants are often utilized. These, however, prove too small on areas where there is very vigorous and luxuriant weed growth unless the aspen plants are repeatedly weeded. On such areas two-year old plants are preferable.

Photograph 95. A small plantation of one-year old transplants. Here the ground vegetation although rich, is not heavy and the one-year old plants are old enough. They have,however, been staked. Haugsjå, Aust-Agder.

In Norway the usual planting distance for either one or two-year old aspen is 2 x 2 metres or approximately 6ft. 6 ins. x 6ft. 6 ins. Owing to the height of the plants the planting is carried out extremely carefully and the roots are well set out in suitable pits. It is essential that the formation of a hole in the soil around the young stem, owing to rocking, be prevented as much as possible. During planting operations every possible care is taken to avoid damaging either the young roots or the stem in any manner whatsoever. Damage of any sort will facilitate the entry of injurious fungi, which at such an early age will render the tree potentially valueless.

Sometimes it is thought necessary to stake each plant, but normally this is unnecessary. A small plantation of one-year old, staked aspen is shown in Photograph 95. Here the weed-growth is not excessive and the planting has been very successful. The site is very suitable for aspen. The large aspen to the left indicates the possibilities of aspen growth on the site chosen.

In Norway there are no plantations of aspen of any great age, and thus the treatment of aspen in plantations has not been undertaken as yet. However, in young plantations experimental pruning work has been started and will be dealt with in the next section.

The treatment of natural aspen is of extreme importance, but it is only in recent years that such treatments have been carried out, as only recently has the aspen become a valuable species for the forest owner. Previously, in many areas the aspen was treated as a weed and many trees were destroyed by ring barking. This was largely because the only use found for aspen was in the match trade and that required first quality aspen only. As has already been stated, aspen has now become an

important species in the veneer trade and also aspen timber has become acceptable to the pulp and paper industries. More and more forest owners are now interested in preserving their aspen stands and in treating them so as to provide the best possible timber from the trees.

Owing to its very rapid growth in its early years the treatment of aspen must commence at a correspondingly early date. Since aspen growth from seed is not normally found, and only very exceptionally in large amounts, the treatment of aspen is concerned with sucker growth, although similar treatments could be applied to aspen growth of seedling origin.

Root suckers of aspen appear most frequently as the initial colonizers of an area after a stand containing aspen has been clear-cut. The first suckers appear in the season after clear-cutting, but naturally additional suckers grow up in subsequent years. Normally a very dense stand of suckers is produced as shown in Photograph 73, where the suckers are from five to six feet tall, the oldest being two years old. Occasionally, however, the regrowth is not so dense as is shown in Photograph 74. Here the old spruce with aspen stand was cut two years before the photograph was taken. On the average, on a reasonably good site five years after a fairly large clear-cutting there are about 7,000 sucker stems per acre, but in the densest parts there may be as many as 28,000 sucker stems per acre. The tallest of these are generally between 10 and 14 feet.

Treatment should begin when the tallest sucker stems are about 10 or 12 feet high, which usually occurs in about the fifth year of growth. Photograph 96. shows some aspen suckers at the stage when treatment should begin.

A year or two before the treatment proper is begun a light cleaning of very poor, twisted stems and unwanted species can be carried out.

The initial treatment consists of a medium thinning. Experiments as described in the next section indicate that the best all round results are obtained with a medium thinning - thinning to an average gap between stems of about five feet. Naturally, only the most vigorous, straightest and most finely branched healthy trees are retained, all other inferior stems being cut out. Since the produce is not saleable this operation should strictly be termed a cleaning but in essence it is more than a cleaning.

Light thinnings are continued at four or five-yearly intervals, only the strongest and best trees being allowed to remain provided that in no instance too large a gap is created in the canopy. If the gaps created are only small and readily filled by the foliage of the branches of the surrounding stems, the stems are able to continue vertical growth, but if the gaps are too large the trees surrounding them will respond to the light and will tend to grow into the space rather than upwards. Thus, always, the thinnings must be made with a view to heliotropism.

A moderately heavy or heavy thinning will lead to the necessity of pruning. With a thinning to a distance between trees of about five feet, natural pruning begins to take effect at about ten years of age when the stems are from two to four inches in diameter. With a larger spacing natural pruning does not occur until the stems are from four to five inches in diameter, or even more, and consequently knotty timber is laid on and the value of the timber diminished. If pruning is necessary the branches should be cut off flush with the stem but every

Photograph 97. Old well-formed aspen which have been neglected. These trees are sufficiently well spaced to respond to treatment. Markings for thinnings were carried out in June 1957. Near Froland, Aust-Agder.

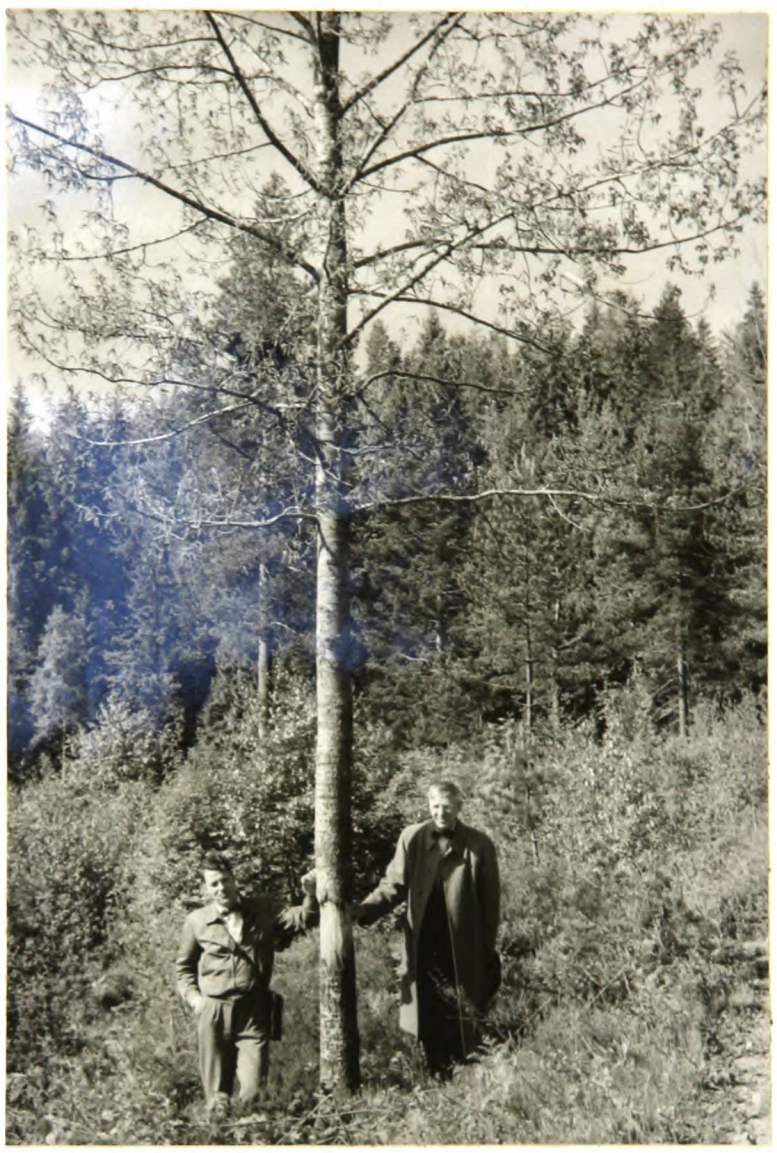
Photograph 98. Seventy-year old aspen in mixed woodland. These trees (middle distance) are too small in diameter for their height. Their crowns are too small to respond to treatment. Near Froland, Aust-Agder.

care must be taken to avoid damaging the bark in any way. A saw will prove to be the safest implement and if a saw with small teeth is used (16 or 24 teeth per inch) there is less likelihood of damage and also the cut surface will be relatively smooth; thus reducing the probability of fungal spores resting on the wounded surface, and hence reducing the likelihood of fungal infection. The height to which pruning should safely be carried out is not as yet definitely known, but if pruning is carried out to a height of half the length of the green crown results should be reasonable.

Since little, if any, treatment of aspen had been carried out in Norway up to the 1940's, the treatment of older natural stands must be considered. Stands of old aspen that are not dense and made up of well formed trees, as in Photograph 97, are easily dealt with provided they are not too old to respond to opening out. It is essential that the aspen crowns should be symmetrical and well formed. A green crown between 33% and 40% of the total height is considered to be best for trees over 30 feet in height. When the crowns are smaller there is little chance of their responding favourably to any opening out of the crown. Thus, unless the trees have grown up with plenty of room, thinning may be too late for effect and thus hardly worth while.

In some areas trees of a height of 70 feet have been grown too closely throughout their lives and have now reached only four inches in diameter. Some are shown in Photograph 98. These trees have very small crowns only extending about one tenth of the total height and obvbously any opening out would be useless.

Aspen in mixture with other species, such as spruce (this mixture being extremely common) presents a slightly different picture as, in general, the spruce



Photograph 99. An aspen tree which has been ring-barked so as to retard sucker growth in a new plantation. The tree is in full flower in June as a result. Haugsjå, Aust-Agder.

has been treated and thus some attention has necessarily been paid to the aspen. Even so, much of the aspen in such mixtures have very small crowns and slender stems. There is little chance of favourable reactions to thinnings amongst older trees, but middle-aged and young trees readily respond to treatment. It is essential to keep the aspen crowns in the light so that well formed, symmetrical crowns of sufficient depth may be maintained through-out their lives.

A special form of treatment is that concerned with the prevention or retarding of root sucker growth. such treatment may become necessary for a number of reasons, the major one, in forestry, being to prevent the formation of root suckers in a new plantation from trees around the margin. This treatment involves the girdling of the old trees by ring barking three years before they are felled. These trees produce green leaves in the first two years after girdling and then usually die. Naturally, to prevent suckers in a clear-cut area, the girdling should be carried out three years before the clear-cutting. A tree so treated is shown in Photograph 99.

Sucker growth may be killed by the use of hormone sprays, but aspen is fairly resistant to such treatment. The most suitable method is summer spraying of the leaves. This should be carried out in the last half of July. Rain, during or just after spraying, can destroy the effectiveness because the solution is washed off the leaves. Spraying should therefore be done in clear weather. A rain-free period of six hours after spraying is essential. Some shoots are always missed the first time and hence a second spraying must be undertaken shortly after the first. The most suitable hormone preparations appear to be a mixture of 2, 4-D and 2,4,5-T-ester, and 2,4,5,-T-ester alone. This is brought out by the following table after

Bylterud (11), which includes other species for comparison.

TABLE 13 Resistance Table to Hormone Preparates.

Resistance classes : 0= 0-10% left alive 3=50-75% left alive
1=10-25% left alive 4=75-100% left alive
2=25-50% left alive

Species	2M-4K-Salt	2,4-D-Salt	2,4-D-ester	2,4-D 2,4,5-T-ester	2,4,5-T-ester
Birch	1	1	0	0	0
Dwarf birch	1	0	0	0	0
Hazel	3	4	2	0	1
Bird-cherry	2	2	2	0	0
Red Elder-berry	4	4	4	3	0
Grey alder	0	1	0	0	0
Aspen	3	4	3	2	2
Rowan	2	3	2	2	2
Willow spp.	1	2	1	1	0
Juniper	4	4	4	4	4

It is probable that better results would be obtained by the use of basal spraying. This involves the spraying of the lower one or two feet of the stems and any roots above the ground. This method would, however, be extremely difficult in dense aspen sucker growth and therefore is rather impracticable.

Photograph 100. Pruning trials in an aspen plantation. A tree before pruning. Oslo.

Photograph 101. Pruning trials in an aspen plantation. The above tree after it has been pruned to a height of one third of the height of the green crown. Oslo.

3. EXPERIMENTAL WORK BEING CARRIED OUT ON ASPEN IN NORWAY

The Frølich's Foundation, at the Norges Landbrukshøgskole was set up in order to study the aspen in Norway. This was in order that knowledge could be obtained regarding the growing of aspen for the match industry. A large number of sample plots were set up in aspen stands in Southern and South Eastern Norway. By repeated measurements and controlled tending operations in these plots it was hoped to obtain much valuable information on the growth and yield of aspen. A volume table has been drawn up and work on taper, form factors etc. has been carried out. These are referred to in another section.

Apart from the sample plots for yield studies, other plots have been laid down for thinning trials and pruning trials, whilst numerous plantations have been formed as provenance trials using many different crossings of Populus tremula, and also crossings of this native species with other aspen species such as Populus tremuloides and Populus Grandidentata. Also some experiments have been started on mixed plantations.

(a) Pruning Trials.

Pruning trials are being carried out on plantations of aspen which are old enough. Very few plantations come into this category and hence the trials have only just been started (1957).

Pruning trials have been started in a small 7 year old plantation of aspen of two origins - (i) Cross between P. tremula from Ås in Akershus and Southern Norway. (ii) Hybrid between P. tremula from Southern Norway and P. tremuloides from Ontario, Canada. The latter is

Photograph 102. Pruning trials in an aspen plantation. Another tree before pruning. The rich grass-herb vegetation should be noted. Oslo.

Photograph 103. Pruning trials in an aspen plantation. The last branch up to half the height of the green crown being removed from the above tree. Oslo.

showing by far the better growth. Pruning has been carried out in both the varieties.

In rows, selected at random, the following sequence of pruning has been carried out: -

1st tree pruned to half of the height of the green crown.
2nd tree pruned to one third of the height of the green crown.
3rd tree pruned to one quarter of the height of the green crown.
4th tree Not pruned.

This sequence is then repeated. The trees are planted at a spacing of 2 m. x 2m.; a spacing which does not produce natural pruning within the first ten years.

Each tree has been marked at breast height and numbered and from each tree the following data have been obtained: -

(a) Total height.
(b) Height of the green crown.
(c) Diameter at breast height (Mean of two readings at right angles as young aspen stems tend to be eliptical in cross section.)
(d) Diameter at the base of the largest branch removed in the pruning.

This latter reading is taken in order to try and establish whether there is any relationship between the largest wound-size and the development of rot.

It is hoped, by means of these pruning experiments, to establish the most appropriate system of pruning in aspen plantations in Norway.

Photographs 100, 101, 102, and 103 show certain trees both before and after they are pruned. The extremely good rate of growth should be noted. The rich grass and herb vegetation indicates that the site is a good aspen site.

It is also well sheltered and is not exposed to damage by large mammals.

(b) Thinning Trials.

Thinning trials have been started in young dense groups of sucker regeneration and have so far produced results which show a very marked improvement in thinned stands as compared with unthinned stands.

The procedure adopted is to use replicated sample plots in areas where uniform site conditions, as well as uniform sucker regeneration, can be found. Two grades of thinning and an unthinned control, are utilized. The heavier grade of thinning introduces a gap of approximately 10 feet and the lighter thinning a gap of approximately 5 feet between the stems.

In some trials the replicated plots are further sub-divided, each grade of thinning being divided into two; an area where all sucker growth and underwood is repeatedly removed and an area where it is retained. This is in order to establish whether there is any difference in growth between the aspen under which all woody growth is removed and the aspen under which such growth is allowed to remain.

The thinning trials are started, as a rule, when the suckers have a mean age of five years. The stage when thinnings should begin is shown in Photograph 96.

A typical thinning trial is that at Hasdalen, Søndeled in Aust-Agder.

Here a spruce stand with a few aspen was clear-cut in 1949, and the thinning operations were commenced in the aspen sucker regrowth in 1954. The three grades detailed above were utilized and three replications were formed.

At the time of the thinning (1954) the mean height of the trees left standing was 4 m. (13.1. feet).

In general the stems are all very fine. In 1957, three years after the thinning, there is a marked difference between the three grades.

In the heaviest grade of thinning the trees are extremely well formed with large diameters and fairly thick lower branches. There is no natural pruning and amongst the large stems there are a considerable number of suckers. The vegetation is luxuriant.

In the medium grade of thinning the trees have not quite reached the dimensions of those in the heaviest grade. But the branching is finer and natural pruning is quite advanced. There are only a very few root suckers as the light reaching the forest floor is not sufficient. Also the vegetation is considerably less luxuriant than that under the more widely spaced trees.

The unthinned trees are very much poorer in general appearance. The height growth is very nearly as good as that in the medium grade but the girths are smaller. Some natural thinning has taken place as has natural pruning, but it is clear that thinning is advantageous. There are signs of unhealthiness amongst the unthinned trees.

The replications bring out the differences well.

It is clear that the next passage, after a four-year interval will yield utilizable produce in both the thinned plots, but not in the unthinned plot.

Thinning plots, though unfortunately not replications, were laid down in older aspen at Haugs/jå in Aust-Agder in 1948.

The hectare over which these plots were laid down, carried a stand of spruce, amongst which were 18 aspen, in 1939 when the area was clear-cut. It was

originally planned to replant the area with spruce, but as the aspen sucker regeneration was so dense it was decided to retain that species.

In 1944 the stand was mapped in detail. Sample quadrats of 2 x 2 m. (6ft.6ins. x 6ft.6ins.), being taken at a spacing of 10m. x 10m. (11 yds. x 11 yds.). All the suckers in each quadrat were counted. A few areas had no suckers but the most densely covered quadrats contained 28 suckers (7 per sq.m. or 6 per sq. yd.). In these, self pruning had started by 1944 and there were up to 3 feet of dead branches. The thickest suckers had a diameter at the butt of 1½ inches and the tallest suckers a height of 14ft. 9 ins. (5 years of age).

In 1944 no treatment was carried out but in 1946 species other than aspen were removed and the densest aspen were cleaned a little.

In the autumn of 1948 the thinning experiments were commenced and three plots of three grades were laid out with neutral bands between each plot. These three grades were (a) light thinning to about 4 feet initially, (b) heavier thinning to about 9 feet initially and (c) no thinning. The thinnings were thus slightly less intense than those mentioned previously. Each of these plots were divided into two in 1955 when half of each plot was cleaned.

The details of the stands in 1955 were as follows:-

TABLE 14. Growth details from a thinning trial in Norway.

After 15 years of growth	Light thinning	Heavy thinning	No thinning
Number of trees per acre	1762	998	3922
Mean height (feet)	30.5	33.2	30.0
Mean diameter B.H. (inches)	2.7	3.5	2.3
Volume of aspen (cu.ft./acre)	1129	1080	1544
Volume of other species (cu.ft./ acre)	34	-	347

Photographs 104, 105 and 106 indicate the nature of the trees in each plot. It is clear that in both the thinned plots there is a very marked improvement in growth and form over the unthinned plots. In spite of this the unthinned plot carries a considerably greater volume, but the trees are smaller in all dimensions although the differences are not great.

It is probable that some pruning will have to be done in the heavily thinned plot, but some natural pruning has occurred. The trees are very vigorous with symmetrical crowns. When crowns are not symmetrical there is a danger of snow break.

The lighter thinned plot has produced an all-round balanced stand, but perhaps a slightly heavier thinning would have produced trees with a larger diameter without incurring the disadvantages of the more heavily thinned plot. Self-pruning has occurred to a greater extent than in the more heavily thinned plot.

Photograph 107. A general view of the stand in which thinning trials are being carried out, before leaf-flush 1957. On the right is the heavily thinned area and on the left the unthinned area. Haugsjå, Aust-Agder.

Photograph 108. A general view of the above stand after leaf-flush 1957. Haugsjå, Aust-Agder.

The unthinned plot is very much poorer than both the thinned plots, but even so the form is fairly good. The crowns are, however, small and, as they only have a relatively cramped space in which to develop, they are somewhat asymmetrical. It is clear that when thinning is left too late the best trees have such small crowns when they are eventually released that they are unable to respond and may even die. The stems also remain too slender and marked bending would occur on release.

Natural pruning and thinning are of course fairly advanced but the dead stems and branches give a somewhat unhealthy look to the stand.

Photographs 107 and 108 give a general view of the area in which the thinning trials are being carried out just before and just after the leaf-flush. Photographs 109 and 110 give a similar comparison within the heavily thinned plot.

The results obtained so far from the thinning experiments indicate that whilst a medium thinning is advantageous, one that is on the heavy side tends to produce trees which are somewhat heavily branched and which do not prune themselves well.

(c) Provenance Trials.

Numerous provenance trials have been started by the Frølich Foundation. Since a relatively large area is required it is difficult to find suitable uniform sites in the forest and hence, where possible, agricultural land is being utilized. Replications are extremely important and normally three replications are used.

The purpose of the trials is to try and determine which of several provenances or hybrids of aspen are most suitable for timber production in Norway.

Photograph 109. A view inside the heavily thinned plot before leaf-flush 1957. Haugsjå, Aust-Agder.

Photograph 110. A view inside the heavily thinned plot after leaf-flush 1957. Haugsjå, Aust-Agder.

All the plants used are propagated, by the means described earlier, in the nursery at the Norges Landbruk-shøgskole at Vollebrekk.

The planting distances vary between 1.3m. x 1.3m. (4ft. 3ins. x 4ft. 3ins.) and 2m. x 2m. (6ft.6ins. x 6ft. 6ins.) and as a rule two year old transplants are used.

Each tree in each of the plots will be measured every four years. The data obtained are entered in detailed forms and the yield, volume etc. computed. All the trees that are felled in the course of thinnings as the stand gets older are cut into 2m. lengths and each section treated as a cylinder. If the stems are under 10 cm. diameter at breast height the calculation of volume is done by multiplying the length by the diameter at mid-height. The trials are, as yet, too young to produce positive results, but in all the trials there are certain provenances, crosses within the species from parents of widely different localities, and hybrids between the species that definitely show a superior initial growth and vigour.

Thus in a small trial in Oslo a hybrid between a southern Norway Populus tremula, and an Ontario, Canada Populus tremuloides shows very much better growth than a cross between P. tremula of southern Norway and Ås in south eastern Norway. This difference is brought out by the mean heights recorded in consecutive years. The plantation was originated in 1951. The mean heights in feet in 1953, 1954, and 1955 were as follows:

	1953	1954	1955
Hybrid aspen	7.5	12.4	14.6
Norwegian aspen cross	3.3.	6.4	8.3

Throughout the trials, the hybrid aspen show an initial growth which is better than that of the various crossings of Norwegian aspen. Whether or not this fine initial growth will continue is open to doubt. No information is available as yet on this point. Also the nature of the timber of the hybrid is not known and for matches the timber of P. tremula is considered superior to that of P. tremuloides. Thus to say that on the initial growth only, the hybrids are better trees may be entirely misleading. Many years must pass before the question is definitely settled.

In Norway, the trials are entirely experimental and as so few plantations of aspen are found there is no possibility of a change-over to the hybrid species. Aspen production in Norway is dependent almost entirely on natural sucker regeneration, and now that treatments are being applied, an improvement in natural aspen growth may be confidently expected.

(d) Mixed Plantations.

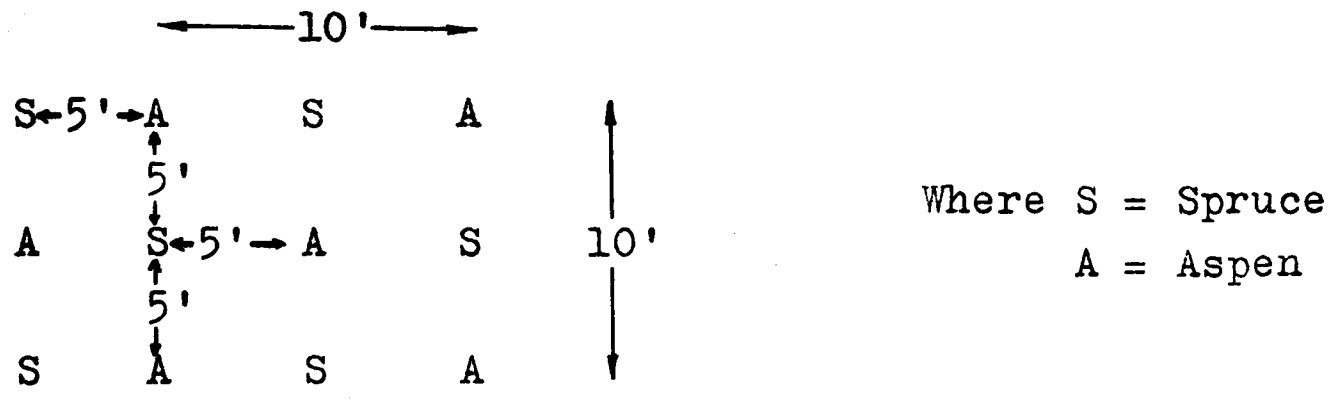
Since aspen often occurs naturally in mixture with a variety of species, and especially with spruce, the formation of mixed plantations is an important consideration in the culture of aspen. Aspen rarely, if ever, occurs singly amongst other species. It is usually found in small groups amongst stands of other species and hence plantations of mixed species by groups might be expected to be most successful. Unfortunately this type of mixture has not been tried, all mixtures that have been made so far are of a stem by stem nature.

At Stavern in the county of Vestfold a mixed plantation of Norwegian aspen and Norway Spruce was created in 1947. The planting was carried out with

Photograph 111. A mixed aspen and spruce plantation. The aspen show extremely good growth. Some stems have been pruned. In the foreground some two-year old transplants, which have been stored overwinter underground, have been planted.
Stavern, Vestfold.

alternating species at a distance of 1½m. x 1½m. (5ft. x 5 ft.) The pattern of planting was therefore as follows:-

Figure 11. Diagram showing method used in planting aspen in mixture with spruce in Norway.



Thus between each aspen there was a space of approximately 10 feet.

Pruning of aspen to about 12 feet was carried out in April of 1957 after 10 seasons of growth.

The position in June of 1957 is shown in Photograph 111. Here it is seen that the tallest aspen are over twice the height of the spruce. The spruce has not been suppressed in any way and is itself showing fairly rapid growth. The aspen are growing extremely well and some have reached about 35 to 40 feet and a girth of 4 inches. Amongst the planted trees some aspen suckers have sprung up and are now a height of 15 feet. Also birch, alder and ash are present in the stand.

This experiment indicates how well aspen and spruce will grow together. The conditions within the stand are excellent, the mixture of litters produces quite a good humus layer in the soil. Both species grow extremely well on this good site and clearly the mixture is successful as both species will produce timber sizes and the spruce will tend to clean the aspen stems. In the future it is probable that the rate of growth of the aspen will

slow down and the spruce will tend to catch the aspen up.

There is still a necessity for further experimental work on the aspen in Norway, and it is hoped that the present work will be continued uninterruptedly and further work started so that the undoubtedly valuable information required may be found out.

PART IV.

THE POSSIBILITIES OF INCREASED USE OF ASPEN IN BRITAIN

1. THE POSSIBILITIES OF NATURAL REGENERATION.

(A). The Possibilities of Natural Seedling Regeneration.

In Part II, the present position as regards natural regeneration by seed was stated. The amount of natural/aspen regeneration by seed occurring in Britain is negligible. Since a study of the distribution of the aspen trees by sexes has not been possible it is impossible to determine whether there is a sufficient mixture of the sexes in any area to obtain abundant fertilization and seeding. But one or two trees of each sex have been found in close proximity in both the Grantown-on-Spey and the central Great Glen areas of Scotland. This indicates that sufficient fertilization to obtain a reasonable quantity of viable seed in most years is possible in these two areas.

Where the occurrence of aspen is more scattered and where great distances occur between successive groups or trees there may be a total absence of fertilization resulting in an absence of seed, or fertilization may be so poor that there is insufficient seed produced to enable a reasonable number to reach a suitable germination bed.

Without precise knowledge of the distribution of the sexes it can be assumed that in areas where aspen is relatively common and where the trees,or groups of trees, occur fairly close together, the aspen will disseminate an abundance of seed and probably a superfluity of seed in most years. In these areas, the possibilities of natural

regeneration should be great, but there is little evidence of successful regeneration by this means. Thus in the time between the ripe seed and the securely established young plant innumerable dangers threaten and largely overcome the aspen. If natural regeneration by seed is to be successful these dangers must be overcome.

A suitable germination bed must be found. For aspen this consists of bare, but not compacted, mineral soil which is sheltered. The shelter which gives a micro-climate suitable for the initial growth of aspen, may be obtained in a broken soil in which there are many small crevices, in a soil with a loose, stony surface or in a sparse moss vegetation. The pappus of the seed itself provides some shelter and it also helps to anchor the seed in small crevices etc. Aspen will not germinate in dry conditions and hence the site should be moist.

Once the seed has germinated the young plant runs many risks. Firstly favourable weather conditions, not excessive in any direction, are absolutely necessary. If it is too dry and hot the seedlings will dry out, and if it is too wet they will be washed away. (This is because up to about the sixth day, the only anchorage the seedlings have, consists of an abundance of hairy rootlets at the base of the radicle. After the sixth day the radicle elongates, the hairs disappear, and a firmer anchorage is obtained. Up to the sixth day anything which tends to break the delicate contact between seed and soil may cause the death of the seedling). A warm, humid period with sufficient precipitation, at the time of germination will be beneficial.

Secondly, lack of light may quickly cause death. Lack of light may be caused by several factors; by the old stand or other tree vegetation, by abundant ground vegetation etc. This latter is probably a major cause

of the lack of seedlings, as at the time (May) when the seeds are shed vegetation is extremely thick and vigorous on most sites and will either prevent the seeds from reaching the mineral soil, or will cause the death of the seedlings by shading.

Thirdly, the aspen seedling is liable to attack by numerous animals and fungi which damage or cause the death of the delicate tissues before the seedling, with its rather poor initial root growth, is properly established.

In Britain suitable aspen germination and establishment sites are few. They occur mainly in small areas, such as at the base of scree slopes where the loose, stony soil affords initial shelter and also sufficient nutrients. Suitable sites are also presented after burning, when the soil surface has not been harmed and where sufficient initial shelter is available.

Generally speaking, there is little possibility of natural seedling regeneration of aspen in Britain. This method is also of little value, except after forest fires, in those countries in which aspen is treated as economically valuable. Where natural regeneration of aspen by seed occurs in Britain it should be encouraged and the resultant stand treated from an early age, as there is a general belief (as yet unproved) that trees of seedling origin will grow better than those of sucker origin. Barth (2) contends that European aspen trees resulting from seed have better form, thinner branches, and better height growth, and are less susceptible to rot than trees of sucker origin.

(B). The Possibilities of Natural Sucker Regeneration.

Sucker growth is the main means of regeneration of aspen throughout its range. In no country do seedlings take its place. In Britain sucker regeneration occurs widely and it is the obvious way in which aspen should be grown, but the sucker growth should receive early attention in the form of cleanings and thinnings.

Aspen sucker regeneration in Britain is open to one major danger; that presented by both domestic and wild herbivorous animals. Cows, horses, sheep, goats, deer, hares, rabbits and voles all prevent, to a large extent, the regeneration of aspen. These animals, as has already been explained, eat back or otherwise cause the death of the young aspen suckers. In most regions, where aspen occurs, there are aspen suckers present in abundance, but nearly everywhere they are eaten back in their first year.

The way in which aspen suckers can grow in an area where grazing by domestic stock has been prevented, has been shown in Part II. (Photographs 53 and 54). This indicates that there are great possiblities for widespread aspen regeneration by means of suckers on open land wherever grazing is banned and aspen trees or live stumps exist. The danger from wild animals is considerable and to ensure an abundant growth of aspen suitable fencing would be required to keep these animals out. By prevention of domestic stock grazing, sufficient aspen suckers would, in the main, be produced.

The areas in which old aspen now occur, could easily and rapidly be restocked if the old trees are cut down and grazing by domestic animals prevented. The resultant sucker growth could then be treated from its

youth and a better growth of aspen obtained.

There are, therefore, in Britain great possibilities of natural regeneration of aspen by means of suckers. If the problem were tackled seriously there appears to be no reason why dense sucker regeneration should not be obtained over wide areas, particularly in Scotland. Whether it is advisable to utilize the aspen now present in the natural flora of Britain as a basis for new generations is another question, which is dealt with later. The fact remains, however, that extensive sucker regeneration is possible (and even becomes a nuisance in some areas) and could be widely used in any attempt to cultivate the aspen.

2. THE TECHNIQUE FOR ARTIFICIAL REPRODUCTION.

(A). The Choice of Strain or Hybrid for Use in Artificial Reproduction.

Before considering a suitable technique for artificial reproduction of aspen in Britain, it is proposed to discuss the choice of the most suitable strain available for such reproduction. Provenance trials with aspen have not been carried out in Britain. Before any widespread planting is done trials should be started.

The strain of aspen now growing naturally in Britain has both a poor growth and a poor form. Also the aspen growth in England and Wales is generally inferior to that in Scotland. The reason for this is not clear but it could be connected with the longer length of day-light during the growing season in Scotland than in England. It is quite reasonable to suppose that with a light-demanding species, this factor may be the cause of better growth further north, but other factors must also be responsible. It has been found in Sweden, that aspen of a northern strain, when grown in more southern latitudes shows a poorer growth. This fact indicates that strains of aspen from more northern latitudes - Norway, Northern Sweden and Finland - may be expected to show decreased growth in Britain. There is more likelihood that a strain or provenance from similar, or more southern latitudes than Britain, will show equivalent or even better growth in Britain. Better growth is unlikely as the British climate is not of a continental nature, as is that where aspen finds its optimum growth conditions in the Baltic States and northern Poland. Polish aspen provenances grown on the Ballochyle Estate in Scotland have not generally shown very good growth (a few exceptions

are to be found, however), and their crowns have tended to bushyness. The part of Poland from which these aspen were obtained is not known and further introductions may prove more suitable.

In artificial reproduction there are two choices open; either the plants can be introduced from another region or pollen may be obtained and used in crossings in Britain. Both of these methods may prove of value in Britain.

Complete introductions from other European countries could be used in trials. Also crossings of European provenances with the native British aspen would provide useful material for trials. For such crossings, only the best of the British aspen should be utilized. Suitable trees are those found in a small area of the valley of the Avon referred to in Part II.3. The locality of this group of better type trees is shown on the map in Appendix I.

In addition to such provenance trials with introductions and crossings within the species, trials using crossings of Populus tremula and Populus tremuloides would be valuable. Such crossings have shown increased initial growth over the native aspen in Scandinavia, and there seems to be no reason why this should not be the case in Britain also. Because of this increased growth, and particularly if it is found to continue in later life, the growing of hybrid aspen would present a more favourable proposition to private woodland owners seeking to find a valuable tree crop.

Once experiments have established which provenances, crosses or hybrids are most suitable for the conditions in various parts of Britain, such strains can be reproduced artificially and used widely.

These considerations assume that suitable markets for aspen timber of all sizes will become established in the future in Britain.

(B). The Technique for Artificial Reproduction.

Artificial regeneration of the aspen must be confined to the raising of seedlings, as regeneration by cuttings (as carried out for most species of Poplar) is very difficult. In former years methods for growing aspen on a fairly large scale have not met with much success and this is probably one of the reasons why the aspen is not popular in British forestry today. Anderson (1) states that if this species (aspen) could be easily grown in the nursery it would be much more highly valued in the forest, both for its timber, rate of growth and silvicultural qualities.

The procedure adopted for raising aspen from seed in both Britain and Norway has been described in Part II. 4c. and Part III. 2. respectively.

In Czechoslovakia, aspen seed for sowing is first passed through a sieve of $2\frac{1}{2}$-3mm. ($\frac{1}{8}$inch) mesh and then through bolting cloth. This procedure yields about one pound of clean seed from ten pounds of catkins. The soil in which the seed is to be sown is cultivated in the autumn or early spring so as to allow time for settling. A fortnight before the time of sowing, brush-wood is spread over, and burned on the beds. The soil is watered before and after sowing. The seed is sown in drills mixed with sand or wood ash in proportion 1:200. After sowing the beds are sheltered with conifer branches and the soil is loosened regularly. The seedlings are thinned to a spacing of $1\frac{1}{4}$ to $2\frac{1}{4}$ inches. With this procedure excellent results are claimed. (Jirkovsky 18).

A Swiss procedure is rather similar to the Norwegian method and like the latter gives practically 100% success. In this method the aspen seed are sown in saturated, compressed peat which lies over mineralized "Terralite" which in turn rests on gravel. A constant water-level is maintained as the whole is placed in a water-tight trough and additional water is added when necessary and the level kept constant. The germination is carried out in a greenhouse. (Marcet 25).

Another writer, (Budke 10) states that excellent results are obtained when twigs one and half feet long and bearing ripe catkins (cut from aspen trees on the day when down appears on them) are stuck into seed-beds so as to secure a natural seed-fall. The beds, previously treated with compost and raked, are shaded with spruce branches. The seedlings require only moderate watering but are sprayed frequently with 1% Bordeaux mixture.

There are thus many different methods used for raising aspen from seed in Europe, and all claim reasonable results. Where the seed is collected from trees in the vicinity of the nursery the methods which involve sowing the seed directly in seed beds are adequate. But if controlled crossings are carried out the use of a greenhouse and boxes for sowing is advantageous. A method based on that utilized in Norway will probably prove to be the most suitable method in Britain.

This Norwegian procedure has been described in detail earlier, but a summary of the method will not be out of place here.

Branches bearing female catkins are brought into the greenhouse before they have been fertilized. These are placed in water; the water being changed daily. When the stigmas open and show their red colouring,

pollen is introduced and fertilization effected. In the greenhouse all the female twigs are isolated from one another by the use of plastic bags. Pollen is introduced either by placing twigs bearing pollen inside the appropriate bag along with the female twig, or is injected into the bag from a syringe. By these means any crosses can be effected in a controlled manner, the pollen being easily transported great distances by air for this purpose. When the seed is ripe it is collected in bags and the origin noted. It should be used at once.

The seed-bed is built up in boxes of any convenient size, (3 ft. x 1 ft. will be found suitable in most instances) but the depth should not exceed three inches. The seed-bed consists of:- 1. a one inch layer of Sphagnum moss, 2. a one inch layer of turf prepared with artificial manure such as "Huminol", and 3. a half inch layer of fine Sphagnum moss. The whole is well watered before the seed with pappus is spread upon the Sphagnum. The seeds are not covered in any way, but the boxes are placed in the shade and germination should commence almost at once.

After the seedlings have become established they should be transplanted into other boxes containing sterilized soil. Both the sterilized soil and the Sphagnum are used so as to prevent weed growth. The seedlings should be placed at about three inch intervals in the second box. These boxes of plants should then be placed outside, all the former operations having taken place inside a greenhouse where a temperature of about 25°C. (77°F.) is maintained. Initial placing outside should be made under shades where the plants harden off. After this the seedlings should be transplanted into beds at about four inches by four inches spacing.

During the first year a growth of up to three feet should be possible and at the end of this the plants should be transplanted into lines with a spacing of one to one and a half inches within, and between, the lines. These spacings will allow adequate growth and will restrict the growth of large side branches. No cutting back should be required if good parent stock has been utilized.

During the seed setting and nursery periods a number of dangers threaten the aspen. Serious damage can be largely prevented by the use of the above method.

Firstly, infection of the catkins after fertilization can be prevented by spraying with fungicide and insecticide. Such diseases as that caused by Taphrina Johansonii or insect attack by Epiblema nicelli can be prevented by this means under controlled conditions whereas, if seed is collected from trees a large amount may be useless.

Secondly, the seedling is free from competition from weeds, as materials free from weed seeds are utilized in the initial stages.

3. THE CHOICE OF PLANTING SITE.

The choice of planting site is the most important consideration for aspen if it is to be used more in the future in Britain. It is not proposed that aspen should replace any of the other leaf-tree species grown in British silvicultural operations, but it is proposed that aspen should take its rightful and proper place amongst these other species. It is not a tree which should be used primarily for timber production, but its other attributes indicate that it should be used as a pioneer and a nurse species. Within these two rôles timber production is of course important and aspen in Britain should be capable of producing a valuable timber, and also in relatively large amounts. Indeed, Anderson (1) in referring to aspen, states: "If the problem were tackled seriously, there seems no reason why all the home match-making requirements should not be met from home forests, even if the species were used only as a nurse."

In Germany the aspen, as in Britain, is not a popular tree, but in that country there is belief amongst foresters that it should be used more. Köstler (20) writing about the aspen states that: "in Germany it (aspen) is at the moment despised as a forest tree and persecuted because its volume production, its value as timber and its biological qualities are not appreciated; its abundant suckering has rendered it particularly unpopular. While no change in attitude has yet taken place towards the aspen, it is bound to come soon."

The belief that aspen can and should assume importance in countries additional to Russia, the Baltic States, Poland and Scandinavia is thus held by some foresters, and there seems no reason why, in Britain,

the aspen cannot be utilized more in silviculture.

In Britain afforestation is normally limited to areas of waste-land; areas which are not suitable for agriculture or other use. Most of these occur in the highland regions where steep, rocky slopes and exposed areas are in the majority. In other regions waste land occurs to a less extent, most frequently on steep slopes, thin soils, and riverine areas subject to flooding or permanently wet. It is primarily in such places that sites become available for forestry and the planting of aspen can be considered on these sites. But also, as aspen rarely occurs in nature over large areas, but is more or less confined in groups of from half a square chain to half an acre in extent, the planting of aspen in "odd corners" in farmland or the like, can also be considered. Site types varying from the very base rich to the highly acid might be available.

As has been previously stated, aspen grows best on fertile moist sites, such as are suitable for most leaf-tree species. These sites are those characterized by a moist grass-herb or a fern (not bracken) vegetation. Since other leaf-tree species which have a greater economic importance will not grow satisfactorily on less fertile sites, preference should normally be given to these, namely, ash, sycamore, elm and oak , whilst walnut or hickory may even on occasion be planted. Aspen, along with grey poplar and alder can, however, be used as a nurse species to these other species on these very good sites. In this rôle it will be able to assist the other species silviculturally, and also provide useful timber. As a nurse species aspen should preferably be grown by groups interspersed amongst the main species, (groups approximately of half a square chain in extent would be

Where moist grass - herb or fern communities occur in small areas only, aspen could then be planted as a pure crop. This would be particularly so in the more northern parts of Britain, as in the south the faster growing hybrid black poplars might occupy these small areas more economically.

On wetter sites carrying a grass-hard rush (Juncus inflexus) type of vegetation, the aspen can be used as a pioneer species or as a nurse to ash, pedunculate oak (Quercus pedunculata) or Norway spruce. Such sites are found on a rich soil which is somewhat heavy or is a compacted, silty soil. Sites of this nature are found mostly along river valleys.

On wet sites where the jointed rush (Juncus articulatus) occurs with grass, aspen can be grown as a nurse to Sitka or Norway spruce which is to be grown on a short rotation.

Where Molinia occurs, either almost pure or with Nardus the aspen can be grown as a nurse to the spruces or thuja. This applies only to such sites below about 1,000 feet and not severely exposed. Site types in which there is a considerable amount of Vaccinium along with grasses and mosses are also suitable for growing aspen. Sites with abundant Vaccinium, Erica, Calluna or Sphagnum are not suitable for aspen although in nature aspen sometimes invades such sites.

In general, any site which is moist and of reasonable fertility can grow aspen provided that the site is not too exposed. In Britain, on sites suitable for the growth of exacting leaf-tree species the aspen can be utilized as a nurse tree by groups, whilst on the poorer, but not too poor sites, the aspen can be used in

a pioneering rôle or as a nurse to the spruces, thuja and perhaps tsuga and the firs. On sites too small to produce economic stands of the above species, the aspen can be grown pure. Everywhere, in mixture, the aspen litter has a beneficial effect on the soil.

It is, therefore, an accommodating species and one that is extremely useful silviculturally, and is capable, provided suitable clones are used, of growing timber of utilizable sizes and of great value.

4. PLANTING AND TENDING TECHNIQUE.

The planting technique for aspen is similar to that used for other poplars (see Part I.7.). Because of the large sizes of the plants (6-7 feet) no notch or other quick methods of planting can be used. Each plant must be pit-planted. The pits should be of ample size to accommodate the roots without undue cramping or bending. The size of the pit will naturally vary with the size of the root that is to be accommodated. Normally, a hole of at least two feet wide will serve, the soil at the base being well loosened and the broken-up turves and any other available organic detritus placed upon it.

Two men are required to plant the tree in the pit, the one holding the plant at the required depth and upright, the other placing loose soil against the roots. Once the tree is planted, the soil around it should be well firmed down, so as to ensure that the tree will not move about in the soil as its top is swayed by the wind. Such movement would cause the formation of a hole around the stem. As the removed turves are placed in the bottom of the pit the soil surface around the stem will be free of weeds initially.

Whilst lifting and planting the young trees, it is essential that physical damage to the stems and roots is prevented as much as possible. Any damage that is caused may lead to early infection by injurious fungal species.

The planting distances used vary with the nature of the site and the purpose of the planting. In most cases group-planting is to be preferred for aspen whether the purpose is for timber production or as a nurse species to a more tender species. The distances utilized should

enable the trees to grow as freely as possible, whilst retaining a certain amount of competition. The distances should be such as to ensure that natural pruning takes place at a reasonably early age (8 - 12 years).

It can be expected that trees planted on the better sites will grow more vigorously and more rapidly than trees planted on the poorer sites. Hence it is legitimate to plant trees on the better sites at a slightly larger spacing than trees on the poorer sites.

On the better sites a planting distance of five and a half to seven feet by five and a half to seven feet is suggested, whilst on the poorer sites four to five and a half feet by four to five and a half feet will be suitable.

The planted area is best fenced against harmful animals, so as to ensure that widespread losses of plants do not occur from this cause. Alternatively, the plants could be painted with some deterrent compound.

The tending technique for aspen will depend on whether the stand is planted or is of sucker origin. (Since natural stands of seedling origin are unlikely to occur, treatment methods for these have been omitted, but they would be similar to that for sucker regeneration).

The treatment technique for aspen in plantations will be dealt with first.

Beeting-up of plantations will only be necessary if large losses have occurred. The failure of odd trees here and there will generally be of little consequence. In small plantations, however, such small failures should be made good as otherwise the remaining trees, surrounding the gap, will tend to grow out into it, as they will respond readily to heliotropism.

In some cases sufficient natural pruning may not occur and some pruning must then be carried out. Experiments into the effect of pruning in plantations are being carried out in Norway (Part III. 3a.) and should also be started in British plantations, but it is hoped that in most, no pruning will be necessary.

Thinnings in plantations will become necessary after some 15 or 20 years. This thinning should be light and made so as to give sufficient growing space for the crowns and roots of the best stems. It is important that thinnings are not left too late and once started they should continue to be made at regular intervals (4 -5 years).

If it is thought desirable an underwood of more shade tolerant species may be established under the middle-aged aspen. This underwood would gradually be released as the aspen is cut and the new species would then take over the site completely. Species which could be used in this manner on their appropriate sites are the spruces, hemlock and the silver firs.

Where aspen is utilized as a nurse species it should be established in groups, and the species to be nursed placed in the gaps between the aspen groups. Within the aspen groups, treatment should be similar to that in other aspen plantations.

The treatment technique for sucker growth is more complex as here an early decision has to be made regarding the trees that are ultimately to form the future stand. In plantations, naturally only good trees will be planted and no further choice is necessary until about the eighteenth year.

Abundant sucker regeneration can be expected in any area where old aspen trees have been cut down, leaving an area of clear ground. The suckers will be able to get away if they are not browsed back and hence, during

the regeneration period stock should be kept from the area. If a sufficiently dense sucker growth is not obtained, the formation of the same can normally be facilitated by wounding the existent roots. Hacking the roots with a spade, or similar tool, will normally suffice, but disc-harrowing has been practised in some countries (35). These methods are naturally conducive of fungal disease and hence should only be resorted to if natural regeneration does not occur in a sufficient density. Subsequent thinning will reduce the number of rotted trees.

The age of the suckers when the first cleaning or thinning is required cannot be predetermined but it is likely to be between the fourth and sixth year. The most suitable time for the first treatment is when the stand has reached a height of about ten or twelve feet; this is dependent on the density and rate of growth of the suckers.

The initial thinning should reduce the number of suckers considerably; on the poorer sites one should aim at an average spacing of from three to four feet between the trees, increasing to five to six feet on the better sites. Only good straight stems with well formed crowns should be left.

After the initial thinning the stand should be lightly thinned, and pruned if necessary, on a four year cycle. The thinnings should always be done so as to leave the best formed trees with symmetrical crowns for the final stand. However, it is not always wise to remove all the poorer trees so as to leave large gaps. The aspen responds very rapidly to heliotropism and the thinnings should always be carried out with this in mind; large gaps should never be created. The final stand

5. THE FUTURE MARKET POSSIBILITIES FOR ASPEN GROWN IN BRITAIN.

The future use of the aspen tree in British silviculture is largely governed by the markets which are likely to be available for the disposal of aspen timber. Much as the species may be desired for silvicultural reasons it is irrational to consider using it if its growth is not economical.

The aspen grown in Britain at present, only exceptionally finds a market in the match-making industry. The aspen is used for little else and virtually there are no markets for aspen at present. Any future increase in the use of aspen must be accompanied by the creation of suitable outlets.

It is reasonable to believe that the British match-manufacturers will accept all aspen which conforms to their specifications, in the future. This is because the aspen (P. tremula) is the most suitable timber and also because importations of the Canadian aspen (P. tremuloides) demand payment in dollars. The increasing need, since the war, to be sparing in dollar expenditure has compelled the Government to impose successive cuts in the allocation to the match industry, and in consequence the industry has been hard pressed to find sufficient timber to keep the factories in production. Every possible economy has been applied including the use of cardboard for match boxes, which normally are made from the same wood as the sticks, and a reduction in the size of the sticks. There also seems to be little likelihood of alternative materials to timber being used for match-manufacture; there is only a very limited demand for book matches in the United Kingdom and not more than

A Match Working Party was set up in 1950 to examine the possibilities of obtaining, from soft currency sources, supplies of woods suitable for making matches. The findings of this Working Party are published in a Report (3) and indicate that with the possible exception of Pinus radiata from New Zealand, none of the species of timbers investigated were capable of providing sticks of satisfactory quality, at least with the existing match-making machinery.

This indicates that poplars, and particularly aspen, will continue to be the main species in demand and future expansion in aspen culture will help to supply this demand from home sources.

Thus for aspen timber of high quality and of large sizes (over 8 inches top diameter under bark) there will always be a ready market in the match industries.

Naturally, not all the aspen grown will be of match timber quality or size, and in order that aspen growing may be economical, additional markets must be created.

It is unlikely that the British plywood industry will utilize aspen, as nearly all the machinery is built to handle large sizes of timber such as the 2 to 3 feet diameter logs imported from West Africa. However, there is a possibility that some factories are or will be equipped to handle small sizes of logs and utilize species such as aspen and birch. The birch plywood industry is very extensive in Scandinavia and imports could be reduced if such industries were created in Britain. Because of its excellent gluing and veneering qualities aspen could find a use in the making of core-stock for more decorative plywood. Such an industry would, however, be only able to utilize sizes similar to those used in the match industry

and would not increase the economic possibilities of aspen.

It is in the industries using wood in a "broken-down" form that a market for small and medium sized aspen such as that produced from thinnings, might be found. In Norway aspen is now used in the pulp and paper industry and for wall-board. Such factories using wood, in Britain, are few, but gradually the number is being increased, particularly of those using small sizes of conifer timber. One factory at Sudbrook is being built to produce pulp from leaf-tree timber. This factory is expected to be in full production by the end of 1957. This mill will require amounts of round small-sized leaf-tree timber amounting to upwards of 36,000 tons per annum. The main species sought initially will be oak, ash, beech and birch, but most other species of leaf-tree including aspen will be acceptable.

This pulp mill and others which it can be expected will be built in the future, will provide an outlet for small sized aspen logs, thus making treatment by thinnings economical.

In addition to the above, it is probable that wall-board factories will be opened that are capable of utilizing some leaf-tree timber. In Norway this industry provides an outlet for aspen which is slightly rotten and a similar outlet in Britain would be invaluable.

Whilst large factories can thus be expected to be capable of utilizing aspen, small industries such as the toy-making industry, will find aspen most suitable to their needs as it is light in weight and colour and takes glues and paints admirably. Once these characteristics become more widely known and appreciated, aspen will undoubtedly be used as sufficient quantities become available.

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The future market possibilities for aspen grown in Britain are considerable, but the use of the species will not become popular until it is realized that trees of a sufficient quality and producing a sufficient quantity of timber are being grown. The qualities of the aspen and its timber should be brought before the public very much more, so as to publicize the species.

PART V.

SUMMARY, AND RECOMMENDATIONS.

The aspen, P. tremula is a very widely distributed species occurring all over Europe and Northern Asia, whilst the closely allied American species, P. tremuloides occurs from the east to the west coast in North America.

The European aspen finds its optimum growth conditions in the silty districts of the Baltic States and Poland, but also is a very important species in the Scandinavian countries and Russia.

The species is slender for its height, has a few fine branches and consequently an open crown. The foliage is characterized by its constant movement, created because the leaf stalks are long and laterally flattened and cannot support the weight of the leaves.

The tree grows mainly in mixture with other species, either conifers or leaf-trees, but also occurs pure in areas of up to an acre in extent. It is extremely light demanding, is capable of spreading by means of seed, but usually spreading by means of suckers occurs extensively everywhere. The aspen is a pioneer species and is capable of colonizing burnt-over land or cut-over land quite rapidly. Because of its light crown, other species (preclimax or climax) can become established and grow up under the aspen.

The tree, in many countries, has been despised, its qualities not being appreciated. Its main use in Europe is for matches and match boxes - for which it is more suitable than any other species. In America it is used primarily for pulp and paper.

The timber is light, both in colour and weight, is finely and evenly textured; there is no appreciable difference between the sapwood and the heartwood; the growth rings and rays are inconspicuous. The wood takes glue and paints well, but does not last well, untreated, when exposed.

Aspen is extremely prone to damage by wood and root rotting fungi, but to a less extent on the sites that suit it best. The presence of rot does not necessarily mean that the timber is of no value. On its best sites the rate of wood production far exceeds the rate of rot extension. Wood-boring and defoliating insect species cause some damage, but this is not normally of a serious nature. Young trees are often damaged by mammals. Despite these diseases and pests the aspen is able to grow and produce satisfactorily in many countries and in recent years aspen culture has received much attention.

In Britain, aspen is an indigenous species, but it has been neglected in forestry operations. The tree is found in most parts of Britain; in England and Wales, mostly as a minor constituent of mixed leaf-tree woodlands in which it occurs in small groups; in Scotland the aspen shows, in general, better growth, and occurs sometimes in pure groups, but most frequently in mixture with birch.

The aspen growth in Britain is extremely poor nearly everywhere. Why this should be so is unknown: both climatic and soil conditions appear suitable for the species and the latitude is similar to that where the aspen grows best. It seems therefore that the strain is not a suitable one. This, combined with an almost total lack of treatment resulting in there being many

decadent, over-mature trees from which rot-fungi spread easily, must account for the poor growth.

From measurements made in aspen in Morayshire and Inverness-shire it appears that whilst the diameter growth is quite reasonable compared with that recorded in other countries, the height growth and hence the volume production is very poor. The average diameter reached is ten or eleven inches and the height 35 to 45 feet. There is a high incidence of rot in Britain; if thinnings had been made the number of badly rotted trees would have been reduced over the years, and the general appearance improved.

Young regrowth does not occur very extensively, largely because most of the sucker growth is eaten back by grazing animals. Where groups of sucker regeneration have been able to grow in areas where grazing has been absent, the growth is quite good. If such groups were treated from an early age, there is every possibility that the resultant growth would be improved, as has been shown at Brandon in Suffolk.

Plantations of conifers in which aspen have been incorporated in a stemwise manner, have been tried on an estate in Argyll. The present condition of these plantations is not good from an aspen point of view, Whilst a few good aspen trees occur here and there amongst the conifers, most have disappeared. It is probable that if the aspen had been planted in small groups instead of singly there would have been more favourable results as fewer trees would have succumbed to competition and through lack of sufficient light.

In Norway, aspen grows very much more successfully especially in the south where it is very common and is the most important leaf-tree species. The form of the aspen, its growth and production are superior to that

obtained in Britain. Some trees of over 100 feet in height are to be found.

The aspen in Norway occurs chiefly in small groups which are most frequently amongst spruce. The best growth is obtained in small areas into which nutrient-rich water flows, but drainage is not impeded. The vegetation on the good sites consists of a luxuriant growth of grasses, succulent herbs and ferns.

Whilst aspen has held an important position in Southern Norway for many years, it is only recently that tending treatments have been practised. Formerly, the only outlet for aspen was for matches and hence only large, mature trees were cut. Thinning, in general, was not practised as there was no outlet for the material produced. The position has changed now as small-sized and even slightly rotted timber is being taken by the pulp and wall-board industries. Tending thinnings are now economic and aspen culture receives much attention.

A foundation for the advancement of aspen management, known as the F.H. Frølich Foundation, has been active for some years. This foundation has its headquarters at the Norges Landbrukshøgskole at Vollebekk where experiments on aspen breeding are carried out. Provenance trials and pruning trials have been set up as have thinning trials in sucker regeneration. These latter show that a greatly increased rate of growth is obtained after thinning dense suckers at an early age (4 - 7 years).

The Foundation and the Norwegian Forest Research Institute have laid out a number of aspen sample plots over much of the south of Norway. From studies made in these, yield tables for two different site types, and a volume table have been constructed.

The yield tables show that in 70 years the standing volume per acre of aspen on site II (medium-good) is 3,847 cu. ft. and on site III (medium-poor) is 3,074 cu. ft. The corresponding figures for the total production (including thinnings) are 7,632 cu. ft. and 5,651 cu. ft.

The treatment of aspen of most ages has proved beneficial and many forest owners are seeking advice on how to treat their aspen stands. Old stands, if they are not too dense, benefit from thinnings, but if stands are too dense and the crowns, in consequence very small, thinnings will not be beneficial. A symmetrical crown which is between a third and forty % of the total height should be maintained for the best growth in older trees.

The keenness with which the Norwegian forest owners are carrying out tending operations in aspen indicates that its culture is considered very much worth while. The species is likely to become even more important both as a timber species and for its silvicultural value.

There seems to be no reason why the aspen should not grow well in Britain. It does so both to the east and to the west where it is a valuable commercial tree as well as being an asset in the forest.

Given the right conditions aspen would be able to spread by seed in Britain as in other countries, but much more important than that is the question of sucker regeneration which is the primary means of spread elsewhere. In Britain the one obstacle in the way of extensive aspen suckering is grazing. Most of the natural aspen occur on rough grazing land, and as the young shoots are extremely palatable, they are always eaten back. It is only in those few areas where

grazing by domestic livestock does not occur that aspen suckers have been able to get away. It seems, therefore, that if grazing were restricted, aspen suckering from old trees or fresh stumps would proceed as in Norway. Wild animals would cause some losses, but it is the effect of the domestic stock that largely prevents widespread sucker growth.

Aspen could therefore be propagated in Britain and its silvicultural value could be utilized as well as the timber which is urgently required in Britain for the manufacture of matches.

Aspen will grow best on the sites which suit the more exacting leaf-tree species, but it also grows reasonably well on poorer soils. In all the suitable sites it could be used as a pioneer or nurse species, and as such would furnish a large amount of useful timber, especially if outlets, such as those in Norway, could be found for the small sizes produced from thinnings. If such markets become available and sizes large enough for match timber are produced, the growth of the species will be economic as well as of great value silviculturally.

There seems to be no reason why aspen should not be utilized more in British silviculture. In view of the fact that as a pioneer, or nurse species, it would be a valuable addition to the trees now in use in silviculture in Britain, it seems feasible to conclude that the aspen should be grown in Britain's managed forests. By not using it, a valuable tree species, indigenous to these islands, is being wasted.

Some recommendations for the proposed propagation of aspen in Britain will now be given.

In order that plants may become generally available, and the most suitable strains selected, an aspen breeding nursery and provenance trials should be set up.

The provenance trials should use a selection of the following:-

a. Plants from European countries.

b. Hybrid plants from European countries.

c. Crosses of the best British aspen with European strains.

d. Hybrids of the best British aspen with P.tremuloides from North America.

The best British type of aspen is thought to be that found in a small area in the river Avon valley in Banffshire, but the best trees in other groups could also be used. The types found to be most suitable for British conditions should be produced in adequate numbers and made available to planters.

Aspen can be used as a pioneer or nurse species on all sites of moderate to good fertility, and moist. Such sites are characterized by vegetation communities as follows: - grass-herb, grass-hard rush, fern, jointed rush-grass, Molinia and Nardus - Molinia.

The species which aspen could nurse satisfactorily, depending on the nature of the site, are:- sycamore, elms, oaks, beech, ash, walnut, spruces, firs, thuja, tsuga and cypresses.

It is recommended that aspen be planted in groups. This corresponds with the natural conditions of growth, for aspen seldom occurs pure over areas larger than one

or two square chains. The size of group planted should vary with the size of the site and the purpose of the planting. Groups up to a half or three quarters of a square chain will be suitable. These will give between five and ten stems at maturity depending on the nature of the site.

The plantations must be thinned as this becomes necessary so as to give the best trees enough room to develop strong, healthy, symmetrical crowns reaching to between a third and forty % of the way down the stems.

Aspen sucker growth should be utilized to re-stock areas carrying a few old trees. These old trees should be removed and the area over which sucker growth is required cleared of any thick vegetation. A dense sucker growth can be expected if grazing is prevented for a few years.

When the sucker growth is about ten or twelve feet high, the growing stock should be thinned to a distance of between three and six feet between stems, depending on site. After the initial thinning, light thinnings should be made regularly and often as for plantations.

If required, other tree species may be introduced beneath the aspen when it is thirty or forty years of age.

A rotation of about 70 or 80 years should be found suitable.

It is also recommended that new markets for aspen be sought in Britain so that the growing of aspen may be economic.

The silvicultural usefulness and the excellent qualities of the timber for various uses should be brought before foresters, wood using industries, and the public in order to advertise the species and promote an increase in its use in Britain.

A P P E N D I C E S

I - X .

APPENDIX I

MAP SHOWING THE OCCURRENCES OF ASPEN IN PART OF SCOTLAND

The region examined lies north and west of the brown line.

LEGEND:-

Main aspen areas of Scotland:-

I, The Grantown-on-Spey or Central Spey Valley Area.

II, The Central Great Glen Area.

Aspen occurrences more or less pure in groups:-

Aspen occurrences occasional in mixed woodland:-

The best type of aspen found in the region:-

REFERENCE

Main Roads with Ministry of Transport Nos.
Other Metalled Roads
Roman Roads
Pipe Lines, water (arrow indicates direction of flow)
Boundaries National
Site of Battle — 1066
Altitudes in Feet
Contours

County
Antiquities — Abbey

Railways — G.W.R. — Station — Station (closed) — Level Crossings
Mineral Lines & Tramways
Church or Chapel with Tower or Spire
Windmill
Lighthouse
Woods
Canal

ERMINE STREET
Vyrnwy Aqueduct

Lightship
Marsh

River — Cliffs

Transverse Mercator Projection.
Origin of Projection 49° N. 2° W

The Altitudes are given in Feet above Ordnance Survey Datum (Mean Sea Level). The Submarine Contours in Fathoms, are taken from Admiralty Soundings.

The representation on this Map of a Road is no evidence of the existence of a right of way.

Scale: Quarter-Inch to One Statute Mile = 1/

5 0 5 10 15
8000 0 8000 16,000 24,000 32,0
Scale of Kilometres
5 0 5 10 15 20 25

The Vertical Interval between the Contours is 200 feet.

A P P E N D I X II.

Key to the Four Main Aspen Species

The aspens are all members of the section Tremulae of the Genus Populus in the family Salicaceae. The aspen species can be identified by the use of the following key drawn up by Houtzagers (16).

1. Leaf-blade generally shorter than 0.07m. ($2\frac{3}{4}$ inches); petiole about as long as the blade. Young branchlets and buds glabrous. . . . . 2.

   Leaf-blade generally longer than 0.07m. ($2\frac{3}{4}$ inches) petiole shorter than the blade. Young branchlets and buds pubescent when unfolding, with tomentum partly persistent during summer . . . . . 3.

2. Leaves round, 0.03-0.05m. ($1\frac{1}{4}$-2 inches) in diameter; leaf margin irregularly and coarsely dentate . . . . . .Populus tremula

   Leaves about the same size, but often somewhat longer while a little accuminate at the apex; leaf-margin more finely and more regularly dentate. Catkins smaller and more slender than those of P. tremula. A larger tree . Populus tremuloides

3. Leaves ovate and rather thick in texture, shining and dark green above, of a paler green beneath . . . . . Populus sieboldii

   Largest leaves of this group, dark-green above, glaucescent beneath. Margin of the leaves on the long shoots coarsely and irregularly dentate; on the short shoots more sharply dentate to serrate, more elliptical. Catkins small . . . . . Populus grandidentata.

A P P E N D I X III.

Local Volume Table for Aspen in the Grantown-on-Spey Area.

The construction of this volume table has been made possible by the adoption of the form factor of 0.5 which has been found to hold for both Norwegian and Swedish aspen. This form factor is assumed to be applicable to British aspen, although proof of this has not been obtained. However, the volume table gives an indication of the timber content of aspen in the Grantown-on-Spey area.

A curve for the average height against girth of the aspen in this area is given in Figure 7. This has been used as a basis for the tables in that, for each quarter girth reading the appropriate height has been used in the following formula to obtain the volume:-

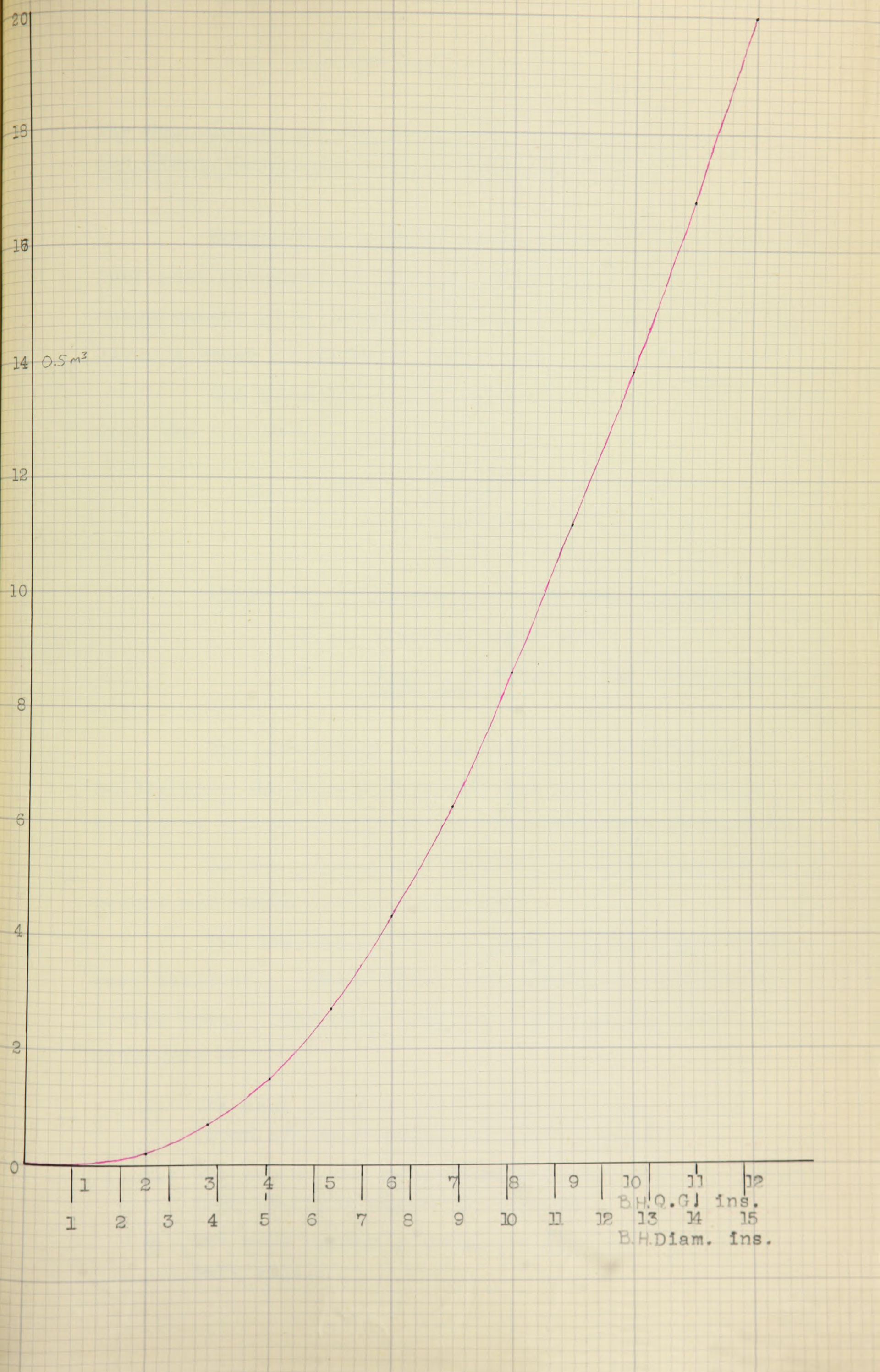
$$V = sfh = \frac{sh}{2} \text{ (since } f = 0.5)$$

where s = basal area
f = form factor = 0.5.
h = height

The volume has been obtained for every quarter-girth inch and the table drawn up:-

Breast-height quarter-girth: inches.	Volume. Hoppus feet.
2	0.2
3	0.7
4	1.5
5	2.7
6	4.3
7	6.25
8	8.6
9	11.2
10	13.9
11	16.85
12	20.0

LOCAL VOLUME TABLE FOR ASPEN IN THE GRANTOWN-ON-SPEY AREA



A P P E N D I X IV.

The Calculation of the Percentage Increment for Aspen in the Grantown-on-Spey Area by Borggreve's Method.

Borggreve's Method for calculating the percentage increment consists of the use of data obtained from measurements of a large number of sample trees. The data cover a range in diameter sizes from 5 to 11 inches.

The percentage basal area increment is obtained from the following formula:-

$$P_b = 100 \times \frac{\sum \frac{4D}{N}}{\sum D^2}$$

where P_b = percentage basal area increment

D = Diameter under bark

N = Number of rings in the last inch of bore spill.

The percentage volume increment is obtained by multiplying the figure obtained from the above formula by 1.2 to 1.4 depending on the rate of growth in height.

In the aspen measured, there is little growth in height and hence 1.2 has been used.

For the calculation, a total of 40 sample trees were measured. These trees were chosen at random over a wide area. For each tree the following data were obtained; -

1. The mean diameter over bark at breast height (mean of two readings at right angles)
2. The sum of two measurements of the bark thickness made at right angles to the stem.
3. The mean number of rings in the last inch of bore spill.

From these data the values for D, N, and D^2 have been calculated and are shown in the table.

Using the above formula, the percentage increment is calculated:-

$$P_b = \frac{100 \times 72.85}{2095}$$

$$= 3.476$$

The total volume increment % = 3.476 x 1.2

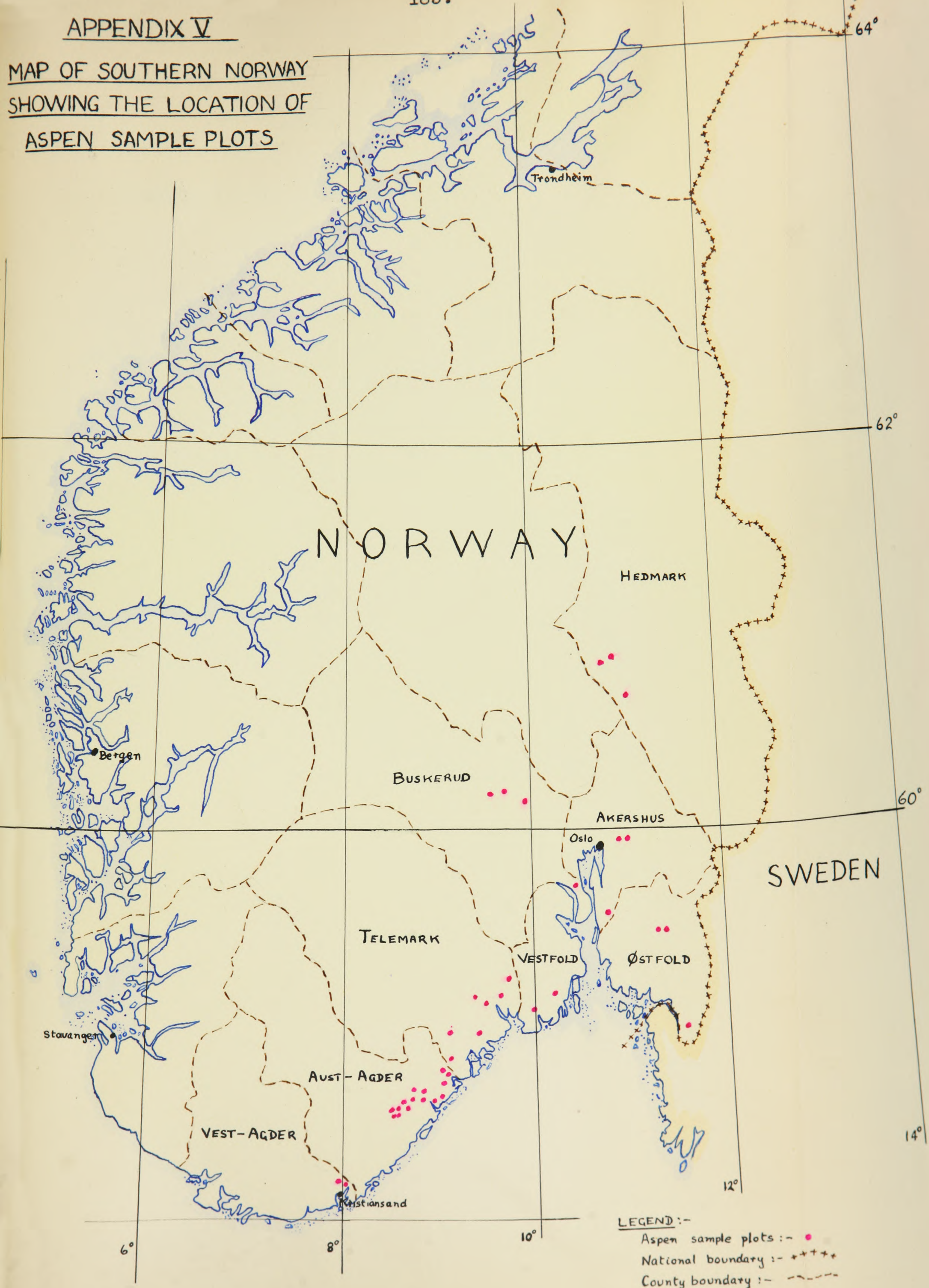
= 4.2%

Data for the Calculation of the Increment by Borggreve's Method

No.of tree	Diameter over-bark in.	Twice bark thickness in.	Diameter under-bark in. D	No.of rings in last inch N	D^2	$\frac{4D}{N}$
1.	5.0	0.42	4.58	9	21.0	2.04
2.	5.2	0.48	4.72	15	22.3	1.25
3.	5.2	0.39	4.81	12	23.1	1.60
4.	5.5	0.47	5.03	9.5	25.3	2.09
5.	5.6	0.50	5.10	11	26.0	1.85
6.	5.7	0.47	5.23	10	27.4	2.09
7.	5.8	0.51	5.29	12	30.0	1.76
8.	6.2	0.50	5.70	13	32.5	1.75
9.	6.3	0.54	5.76	14.5	33.2	1.58
10.	6.5	0.52	5.98	15	35.8	1.59
11.	6.7	0.57	6.13	16	37.6	1.53
12.	7.0	0.58	6.42	14.5	41.2	1.77
13.	7.0	0.49	6.51	13.5	42.4	1.90
14.	7.1	0.60	6.50	17	42.2	1.53
15.	7.2	0.65	6.55	13	42.9	2.01
16.	7.3	0.57	6.73	12	45.3	2.24
17.	7.5	0.66	6.84	15	46.8	1.82
18.	7.5	0.62	6.88	14.5	47.3	1.90
19.	7.6	0.59	7.01	16	49.1	1.75
20.	7.7	0.62	7.08	13	50.1	2.17
21.	7.8	0.67	7.13	14.5	50.8	1.95
22.	7.8	0.80	7.00	19	49.0	1.47
23.	7.9	0.67	7.23	15.5	52.3	1.86
24.	8.0	0.62	7.38	17.5	54.5	1.69
25.	8.1	0.65	7.45	16	55.5	1.86
26.	8.3	0.82	7.48	19.5	56.0	1.53
27.	8.5	0.72	7.78	18	60.5	1.73
28.	8.5	0.65	7.85	15	61.6	2.09
29.	8.6	0.97	7.63	17	58.2	1.79
30.	8.8	0.64	8.16	16	66.6	2.04
31.	8.9	0.99	7.91	20	62.6	1.58
32.	9.0	0.78	8.22	19	67.6	1.73
33.	9.2	0.77	8.43	19	71.1	1.77
34.	9.4	0.70	8.70	17	75.7	2.04
35.	9.5	0.85	8.65	21	74.8	1.65
36.	9.7	0.72	8.98	18.5	80.6	1.93
37.	10.0	0.79	9.21	19.5	84.8	1.88
38.	10.4	0.80	9.60	20	92.2	1.92
39.	10.7	0.78	9.92	18	98.4	2.24
40.	11.1	0.75	10.35	22	100.7	1.88
				TOTAL:-	2095.0	72.85

APPENDIX V

MAP OF SOUTHERN NORWAY SHOWING THE LOCATION OF ASPEN SAMPLE PLOTS



LEGEND :-

Aspen sample plots :- •

National boundary :- +++++

County boundary :- ---

SCALE :-

1 inch = 39·46 miles.

G.H.Powell.
5.8.57.

A P P E N D I X VI.

Summary of the Data Obtained from the Norwegian Aspen Sample Plots.

The data in the following table were obtained from the latest measurements in the aspen sample plots of the Frølich Foundation. For convenience, the figures in the table have been converted from the metric to the British system.

Summary of the Data Obtained from the Norwegian Aspen Sample Plots

Plot No.	District and County	Ht. above sea level ft.	Age yr.	Standing trees: Mean Ht. ft.	Mean diam. in.	Mean vol./acre cu.ft	Current annual increment per acre: Aspen cu.ft	All spp. cu.ft	Mean annual increment %
1.	Ås, Akershus.	230	30	51	6.5	166	8.6	9.6	4.7
2.	Holt, Aust-Agder.	215	48	72	9.9	273	14.5	14.5	3.9
3.	Holt, Aust-Agder.	115	39	58	7.2	147	14.3	14.4	12.6
4.	Froland, Aust-Agder.	280	53	73	9.4	265	14.5	16.3	5.7
5.	Froland, Aust-Agder.	360	52	83	9.5	339	22.6	22.7	5.6
6.	Holt, Aust-Agder.	360	55	65	8.3	176	8.5	11.4	4.3
7.	Vennesla, Vest-Agder.	165	44	57	6.6	170	14.3	15.8	9.5
8.	Tveit, Vest-Agder.	115	58	68	9.2	183	6.9	10.1	3.8
9.	Vegårdshei, Aust-Agder.	245	48	69	7.5	242	16.8	16.9	4.9
10.	Vegårdshei, Aust-Agder.	265	47	61	6.3	164	14.4	14.6	7.5
11.	Vegårdshei, Aust-Agder.	425	46	68	8.0	200	12.1	12.9	4.7
12.	Stange, Hedmark.	690	56	66	7.8	172	3.2	8.1	1.4
13.	Sandar, Vestfold.	100	46	56	6.4	185	9.7	10.5	4.4
14.	Brunlanes, Vestfold.	130	36	47	5.2	134	12.0	12.0	8.1
15.	Gjerpen, Telemark.	330	45	65	8.7	270	13.3	13.3	3.9
16.	Solum, Telemark.	430	--	80	5.2	365	15.0	15.0	4.6
17.	Drangedal, Telemark.	245	43	72	7.2	326	15.7	15.7	4.0
19.	Sannidal, Telemark.	330	48	52	5.8	166	9.4	9.4	5.4
20.	Søndeled, Aust-Agder.	50	45	67	6.1	223	7.9	7.9	2.6
21.	Søndeled, Aust-Agder.	30	46	68	6.7	212	11.7	11.7	4.8
22.	Søndeled, Aust-Agder.	130	46	65	6.6	275	15.5	15.8	4.9
23.	Froland, Aust-Agder.	195	45	69	8.8	244	12.1	14.1	4.7
24.	Froland, Aust-Agder.	245	45	63	7.9	210	9.7	9.9	4.0
25.	Froland, Aust-Agder.	280	41	49	4.8	104	6.5	7.2	5.0
26.	Norderhov, Buskerud.	1310	51	65	7.2	269	16.8	16.8	6.2
27.	Norderhov, Buskerud.	1480	48	62	7.5	205	9.9	9.9	3.0
28.	Bamble, Telemark.	310	42	52	6.1	130	7.2	7.2	5.0
29.	Idd, Østfold.	460	72	86	13.6	416	16.8	16.8	3.5
30.	Røyken, Buskerud.	265	39	64	8.3	242	10.1	11.9	4.7

A P P E N D I X VII.

Volume and Yield Tables for Norwegian Aspen.

The material for the volume and yield tables for Norwegian aspen has been gathered in South Norway by the F.H. Frølich Foundation and the Norwegian Forest Research Institute. The data originates from forty sample plots scattered over the principal aspen-growing regions of South Norway. (5).

For the volume table 1,262 trees were measured, out of which one-half were measured with 1-m. long sections, and the remainder with 2-m. long sections. The great majority of the trees were taken out in thinnings of sample plots. Nevertheless, they are considered as rather representative of the aspen which is brought on to the market in Norway today.

As aspen is mostly marketed unbarked in Norway, all the calculations apply to the volume over bark. The volume of the bark can be obtained from the equation:-

$$B_p = 1.312 + 15.301 \frac{B}{D}$$

where B_p = Bark volume%, B = double bark thickness at breast height, and D = diameter at breast height.

The yield tables have been drawn up by the Frølich Foundation and represent data taken from all the sample plots on the respective sites. No details of the yield after the seventieth year are known. The tables refer to over bark measure.

Both the volume table and the yield tables have been converted from the Metric to the British system of measurement. It should be noted that all volumes recorded are in true measure (Cubic feet) and not in quarter-girth measure (Hoppus feet). To convert to Hoppus feet the true volume figure should be multiplied by 0.7854.

Breast-ht. diameter		Height to nearest ½ foot																								B.H.D.
cm.	in.	19.5	23.0	26.5	29.5	33.0	36.0	39.5	42.5	46.0	49.0	52.5	56.0	59.0	62.5	65.5	69.0	72.0	75.5	78.5	82.0	85.5	88.5	92.0	95.0	98.5	in.
6	2.4	0.32	0.35	0.39	0.46	0.49	0.56	0.60	0.67	0.71	0.74																2.4
7	2.8	0.42	0.49	0.56	0.63	0.67	0.74	0.81	0.88	0.95	1.02	1.09	1.16														2.8
8	3.1	0.53	0.63	0.71	0.81	0.88	0.99	1.09	1.16	1.27	1.34	1.45	1.52	1.62	1.73												3.1
9	3.5	0.67	0.81	0.92	1.02	1.13	1.27	1.38	1.48	1.59	1.69	1.80	1.94	2.05	2.15	2.26	2.40										3.5
10	3.9	0.85	0.99	1.13	1.27	1.41	1.55	1.69	1.84	1.98	2.12	2.26	2.40	2.51	2.65	2.79	2.93	3.07									3.9
11	4.3	1.02	1.20	1.34	1.52	1.69	1.87	2.05	2.19	2.37	2.54	2.72	2.90	3.07	3.21	3.39	3.57	3.74	3.92								4.3
12	4.7		1.41	1.62	1.80	2.01	2.23	2.44	2.61	2.83	3.04	3.21	3.43	3.64	3.85	4.03	4.24	4.41	4.59	4.80							4.7
13	5.1		1.69	1.91	2.12	2.37	2.61	2.86	3.07	3.32	3.58	3.78	4.02	4.27	4.52	4.73	4.94	5.12	5.30	5.51	5.72						5.1
14	5.5			2.19	2.47	2.75	3.04	3.29	3.58	3.85	4.13	4.41	4.66	4.91	5.19	5.44	5.68	5.90	6.11	6.36	6.60						5.5
15	5.9			2.51	2.86	3.18	3.50	3.78	4.10	4.41	4.70	4.98	5.26	5.55	5.86	6.18	6.46	6.71	7.03	7.31	7.60	7.88					5.9
16	6.3			2.97	3.32	3.64	3.96	4.31	4.63	4.98	5.30	5.61	5.97	6.29	6.60	6.96	7.28	7.60	7.94	8.26	8.58	8.93					6.3
17	6.7				3.71	4.06	4.45	4.80	5.19	5.55	5.93	6.29	6.68	7.06	7.42	7.80	8.16	8.54	8.90	9.28	9.64	10.0	10.4				6.7
18	7.1				4.10	4.52	4.94	5.37	5.67	6.18	6.60	7.03	7.45	7.88	8.26	8.68	9.11	9.54	9.96	10.4	10.8	11.2	11.6	12.1			7.1
19	7.5					4.98	5.48	5.93	6.39	6.85	7.31	7.80	8.26	8.72	9.18	9.64	10.1	10.6	11.1	11.5	12.0	12.4	12.9	13.4			7.5
20	7.9					5.51	6.00	6.53	7.03	7.56	8.08	8.58	9.11	9.60	10.1	10.7	11.2	11.7	12.2	12.7	13.3	13.8	14.3	14.8	15.3		7.9
21	8.3						6.60	7.17	7.74	8.30	8.86	9.43	10.0	10.6	11.2	11.7	12.3	12.9	13.4	14.0	14.6	15.1	15.7	16.3	16.8	17.4	8.3
22	8.7						7.20	7.84	8.44	9.08	9.72	10.3	11.0	11.6	12.2	12.8	13.5	14.1	14.7	15.3	15.9	16.6	17.2	17.8	18.4	19.1	8.7
23	9.1							8.51	9.22	9.89	10.6	11.3	11.8	12.6	13.3	14.0	14.7	15.3	16.1	16.7	17.4	18.1	18.8	19.4	20.1	20.8	9.1
24	9.4							9.25	9.64	10.7	11.5	12.2	13.1	13.7	14.5	15.2	15.9	16.7	17.4	18.2	18.9	19.6	20.4	21.1	21.9	22.6	9.4
25	9.8							10.0	10.8	11.6	12.4	13.3	14.1	14.8	15.7	16.5	17.3	18.1	18.9	19.7	20.5	21.3	22.1	22.9	23.7	24.5	9.8
26	10.2								11.7	12.6	13.4	14.3	15.5	16.1	16.9	17.8	18.6	19.5	20.4	21.3	22.2	23.0	23.9	24.8	25.6	26.5	10.2
27	10.6								12.6	13.5	14.5	15.4	16.3	17.3	18.2	19.1	20.1	21.0	22.0	22.9	23.8	24.8	25.7	26.7	27.6	28.6	10.6
28	11.0									14.5	15.5	16.5	17.5	18.6	19.5	20.6	21.6	22.6	23.6	24.6	25.6	26.6	27.8	28.6	29.7	30.7	11.0
29	11.4									15.5	16.6	17.7	18.8	19.9	20.1	22.0	23.1	24.2	25.3	26.4	27.3	28.5	29.6	30.7	31.8	32.9	11.4
30	11.8										17.7	18.9	20.1	21.2	22.4	23.6	24.7	25.9	27.0	28.2	29.3	30.5	31.7	32.8	34.0	35.1	11.8
31	12.2										18.9	20.2	21.4	22.6	23.9	25.1	26.4	27.6	28.8	30.1	31.3	32.5	33.8	35.0	36.3	37.5	12.2
32	12.6										20.1	21.5	22.8	24.1	25.4	26.7	28.1	29.4	30.7	32.0	33.4	34.6	36.0	37.3	38.6	39.9	12.6
33	13.0											22.8	24.2	25.6	27.0	28.4	29.8	31.2	32.6	34.0	35.4	36.8	38.3	39.7	41.0	42.5	13.0
34	13.4											24.2	25.7	27.2	28.6	30.2	31.6	33.1	34.6	36.1	37.6	39.1	40.6	42.1	43.5	45.1	13.4
35	13.8											25.6	27.2	28.8	30.4	31.9	33.5	35.1	36.7	38.2	39.9	41.4	43.0	44.6	46.1	47.7	13.8
36	14.2												28.7	30.4	32.1	33.8	35.4	37.1	38.8	40.4	42.1	43.8	45.5	47.1	48.8	50.5	14.2
37	14.6												30.4	32.1	33.9	35.6	37.4	39.2	40.9	42.7	44.5	46.3	48.0	49.8	51.5	53.3	14.6
38	15.0												32.0	33.8	35.7	37.6	39.4	41.3	43.2	45.0	46.9	48.7	50.6	52.5	54.3	56.2	15.0
39	15.4													35.6	37.6	39.6	41.5	43.5	45.5	47.4	49.4	51.3	53.3	55.2	57.2	59.2	15.4
40	15.8													37.5	39.5	41.6	43.6	45.7	47.8	49.8	51.9	54.0	56.0	58.1	60.2	62.2	15.8

Volume Table

for

Norwegian

Aspen

(Cubic feet)

(after Børset,5)

YIELD TABLE FOR ASPEN ON NORWEGIAN SITE II

Age yrs	Standing trees					Felled trees					Current Annual Increment		Mean Annual Increment
	Number of trees	Mean Diam. ins.	Mean Height feet	Basal Area/acre sq ft	Volume/ acre cu ft	Number of trees	Mean Diam. ins.	Mean Height feet	Basal Area/acre sq ft	Volume/ acre cu ft	cu ft/acre	%	cu ft/acre
18	1027	2.5	35.1	36.0	670								36.3
22	800	3.3	39.4	47.4	1001	227	2.1	36.7	5.7	100	109	12.3	50.0
26	628	4.0	45.3	56.2	1315	172	2.8	41.7	7.8	172	122	9.8	62.9
30	499	4.8	50.5	63.6	1630	129	3.6	46.9	9.1	229	133	8.4	71.5
34	402	5.6	55.1	69.7	1931	97	4.4	51.5	10.0	268	138	7.4	78.6
38	328	6.5	59.7	74.9	2201	74	5.2	56.1	10.9	300	149	6.7	87.2
42	272	7.4	64.3	80.2	2488	57	6.1	60.4	11.3	343	153	6.1	93.0
46	228	8.2	68.2	84.6	2746	43	6.9	64.6	11.3	358	154	5.5	98.7
50	195	9.1	72.8	88.5	2841	34	7.8	68.6	11.3	372	152	5.0	102.9
54	168	10.0	75.8	92.3	3203	26	8.7	71.8	10.4	372	147	4.5	105.8
58	147	10.9	79.1	96.3	3403	21	9.5	75.1	10.4	358	140	4.0	108.6
62	131	11.8	81.7	99.3	3575	16	10.4	77.7	9.6	343	129	3.5	110.1
66	119	12.6	84.3	102.3	3732	13	11.1	80.4	8.3	300	114	3.0	110.1
70	109	13.3	86.3	105.4	3847	10	11.9	82.3	7.4	268	98	2.5	108.6

YIELD TABLE FOR ASPEN ON NORWEGIAN SITE III

Age yrs	Standing trees					Felled trees					Current Annual Increment		Mean Annual Increment
	Number of trees	Mean Diam. ins.	Mean Height feet	Basal Area/acre sq ft	Volume/ acre cu ft	Number of trees	Mean Diam. ins.	Mean Height feet	Basal Area/acre sq ft	Volume/ acre cu ft	cu ft/acre	%	cu ft/acre
22	1037	2.3	33.1	29.6	529								24.4
26	804	3.0	37.7	40.9	801	230	1.9	34.1	4.4	72	89	12.7	34.3
30	636	3.7	42.0	48.8	1073	172	2.6	38.4	6.1	129	98	10.0	42.9
34	508	4.5	46.6	56.2	1327	128	3.3	43.0	7.4	172	109	8.4	50.0
38	412	5.3	50.8	62.3	1587	96	4.0	47.2	8.3	200	116	7.4	57.2
42	339	6.0	54.8	67.5	1845	73	4.8	51.2	9.1	243	120	6.6	62.9
46	283	6.9	58.7	71.9	2073	56	5.6	55.1	9.6	257	123	5.9	68.6
50	240	7.6	62.3	76.2	2288	43	6.3	58.7	9.6	268	122	5.3	72.9
54	206	8.4	65.6	80.2	2488	34	7.1	62.0	9.1	268	119	4.7	75.8
58	181	9.2	68.6	83.4	2660	26	7.8	65.0	8.7	268	113	4.2	78.6
62	160	9.9	71.2	86.5	2817	20	8.5	67.6	7.8	257	105	3.6	80.1
66	145	10.6	73.5	89.3	2980	15	9.2	69.9	7.4	243	93	3.1	81.5
70	133	11.2	75.4	91.5	3074	12	9.8	71.5	6.1	200	78	2.6	81.5

A P P E N D I X VIII

The Manufacture of Match Sticks and Match Boxes.

The general procedure in the manufacture of matches and match boxes is similar in most countries although each company naturally has its own jealously guarded secrets concerning the details.

The timber to be used for matches and match boxes, after storage in the factory yards where it is continuously sprayed with fungicide, is cut into billets about 2 feet long. These billets are then barked and sorted before veneers are cut from them.

Two thicknesses of veneer are cut depending on whether the particular batch is for boxes or sticks. For match sticks a veneer of 2.35mm. thickness is used and for match boxes a veneer of 0.6mm. Both are cut in a similar fashion on a rotary veneer cutter. The billets are cut down to a core of about 3 inches diameter. These cores are variously used:- for axles in paper rolls, for packing boxes or for wood wool.

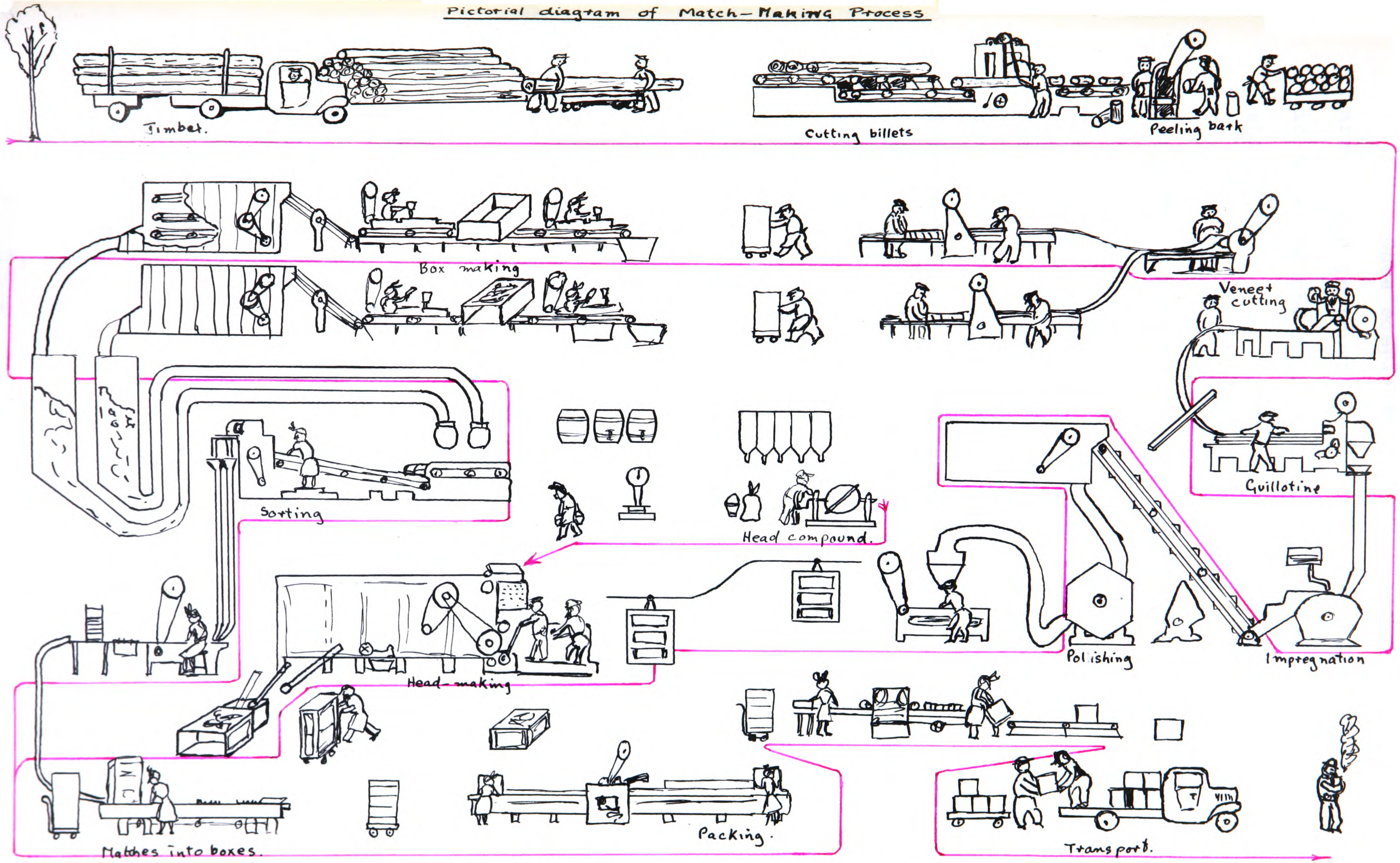
The match stick-veneer is stacked in layers about eight feet long and taken to the guillotine where the actual sticks are cut. The machine is capable of cutting a million sticks in six or seven minutes. The cut sticks are then impregnated with a solution of ammonium phosphate to prevent afterglow. The match sticks are transported by means of vibrating conveyor belts and small and mis-shapen ones fall through holes and are weeded out. After impregnation the matches are conveyed to drying ovens and then to polishing drums where they are whirled around in steel cylinders until they

are rubbed and polished smooth. The next stage is to assemble the sticks in straighteners from which they are passed on to trays each holding about thirty thousand. The sticks are now ready for the continuous match making machine. This machine takes the match stick, soaks the end in paraffin wax, applies the chemical composition to its head, dries it, puts it into its box and closes the lid. In this machine the trays of matches are fitted in place on a slowly moving belt. First they pass through a bath of hot paraffin wax, are dipped in the liquid chemical composition to form the head and are then dried. This drying takes nearly an hour, during which the matches are continually moving. After this the matches are automatically placed in their boxes in the correct numbers. The match is now home but the inner box has to find its outer cover before being automatically closed and jerked on to a table where the boxes are collected prior to having the striking surface painted on their sides.

Whilst the match sticks follow their course, the thinner box-veneers are converted into inner and outer boxes. This is done by stamping out pieces of veneer of correct size and scoring these where necessary to facilitate bending. The boxes (inner or outer) are then assembled, covered with paper and carried by conveyor belts to the place where they are to be filled.

Whilst most makes of match have a wooden outer box, some have cardboard or part cardboard inner boxes. Occasionally the whole box is of cardboard; these were common during World War II.

Pictorial diagram of Match-Making Process



From; Orientering for Målere av Fyrstikkosp.
Bryn-Halden & Nitedals Tændstikfabrik A/S.

Once completed the boxes and their contents are packed in paper in dozens or half-dozens and then in boxes of one gross, and crates of eight gross for shipment.

The Bryant and May Ltd. match factory in London produces 10,500 gross match boxes full in an eight and a half hour day.

The complete operation carried out in the manufacture of match sticks and match boxes is shown diagrammatically. This diagram is based on the procedure used in the Stavern factory of the Bryn-Halden and Nitedals T ndstickfabrik A/S, Norway. A factory situated in the main aspen growing area and one that uses only aspen timber.

A P P E N D I X IX.

Comparison of the Specifications for Veneer and Match Timber in Norway.

Veneer timber	Match timber	
Solid rot allowed in the centre - up to ¼ of the top diameter.	No rot allowed in logs with a middle diameter of less than 9 inches, otherwise a central solid rot of less than 2 inches is allowed.	Rot
Must be straight	Sharp bends must be cut out, but narrow bends allowed.	Crookedness.
Must be free from visible knots.	Single knots are allowed up to 1½ inches in diameter. Large knots and ring knots not allowed (cut out).	Knots
Cuts from axes, hooks, etc. must be cut out according to the extent of the damage. If there is fluting there must be additional compensatory thickness. No badly damaged stems are taken.	Fluting, cuts, spiral growth and ring shakes are all cut out.	Other defects.
The following lengths are acceptable according to the top diameter. Diameter from 8.3 to 11.6 inches: lengths from 9ft.6ins. to 26ft.3ins. When diameter is over 12 inches also utilize lengths down to 5ft.	Any lengths between 10ft. and 23ft. taken but if faultless, large timber down to 6ft.6ins. can be utilized but the price is reduced by 10-15%.	Length
8.3 inches and over	Minimum size taken 7 inches on narrowest diameter under bark.	Top diameter
Unbarked	Unbarked	Bark
Winter felling	Fresh Winter felling	Felling.

Where defects are "cut out", the log is taken but less is paid for it.

A P P E N D I X X.

Description of the Insects Causing Damage to Aspen and the Nature of the Damage.

Order: HEMIPTERA.

Family: APHIDIDAE.

Phemphigus bursarius L. The Gall forming Aphid.

This species causes the formation of pear-shaped or purse-like galls on the leaf-stalks of aspen and other poplars and occasionally on the mid-rib of leaves. The young aphids are born within the gall which may develop to more than half an inch in length. The young aphids feed and develop inside the galls and emerge in late August when they disperse over the surface of the leaves where they feed and produce heavy secretions of honey-dew.

Phemphigus spirothecae Passerini, The spiral-gall Aphid.

This is a closely allied species which causes the formation of spiral-shaped galls on the leaf stalks of aspen.

Pterochlorus saligna Gmelin, The poplar-bark Aphid.

This species which is common and widely distributed often occurs in dense colonies on branches and twigs of poplars and willows. The colonies sometimes measure upwards of a foot in length with a width of two or three inches, and may consist of several hundred individuals. Sometimes the bark of young seedlings and root suckers is attacked.

Melantherium salicis L. The Willow-bark Aphid.

Despite its common name this species also attacks the bark of poplars. It sometimes forms colonies containing several thousand individuals. Both this and the previous species cause considerable damage to both willows and poplars. It seems possible that migration between poplars and willows takes place. It is also probable that both these aphids are associated with the occurrence of bacterial and fungoid diseases of the branches or crowns of poplars and willows.

The Poplar-leaf Aphids.

Several species of aphids may be found feeding on the leaves of aspen. Chaitophorus leucomelus Koch. and C. populi L., are probably the commonest. The former causes the formation of blisters or bladder-like swellings on the leaves. This species is probably associated with the occurrence of the fungus Taphrina aurea.

Order: LEPIDOPTERA.

Family: SESIIDAE.

Sesia apiformis Cl., The Hornet Clearwing Moth.

This moth is a destructive pest of poplars and willows and occasionally breeds in lime and ash trees. The adult insect has a wing span of about an inch and a half. The head is yellow, and the thorax brown with four yellow spots; the abdomen is yellow, with the first and fourth segments black and clothed with brown pubescence. The other segments are bordered with black, and the last three are brown on the back and have a line of black on the sides. The wings are transparent, with

the borders, the nerves, and a transverse stripe on the fore-wings, rusty-brown. The fringes are tawny.

The adults lay their eggs in the bark at the base of the tree during June and July. The larvae first feed on the bark and the cambium and then bore into the wood at the base of the stem or into the root buttresses where they over-winter at the end of the first season. After burrowing in the wood during the second season, they pupate in cocoons at the entrance of their tunnels. The larvae are a pale yellow in colour, with brown heads and legs. When full-grown they are about an inch in length.

The pupa is chestnut coloured and when the moth is about to emerge, the pupa wriggles into the front portion and projects through an aperture in the bark and the empty pupal skin remains in that position after the emergence of the moth.

When a tree has been infested over a period of years, the outer layers of wood become honeycombed with the larval tunnels. Heavily infested trees tend to dieback from the top, and are sometimes killed outright.

Family: COSSIDAE.

Cossus cossus L. The Goat Moth.

The Goat Moth is a large, stout-bodied moth. It has a wing-span of between two and a half and three and a half inches, the female being larger than the male. The moth, in colour, is of a mixture of brown, grey and black.

The insect breeds in the stems of many species of leaf-tree, but is primarily a pest of the poplars. It seems to prefer isolated or well spaced trees, although trees growing in close stands are sometimes attacked.

The eggs, several hundred from each female.

are laid in batches in crevices in the bark, generally within a few feet of the ground. On hatching the larvae burrow into the bark and over-winter. In the following spring they burrow into the wood. The tunnels are oval in shape. From time to time tunnels are bored to the surface to allow the ejection of frass and excrement. In a heavily infested tree large numbers of fully developed larvae may be present.

The larvae may grow to three inches in length. The head is black, and on the first segment there is a dark shield; the sides and underpart of the rest of the body are pale yellow, and the upper part is shiny dark red; the body is sparsely furnished with bristly hairs. As a rule the larvae pupate in coarse cocoons near the surface of the wood, but where there is a heavy attack some of the larvae may leave the tree and pupate in the soil. The pupae are reddish-brown with lighter stripes on the abdominal portions.

The moth selects all sizes of tree for breeding purposes, but damage is usually of more importance economically when small trees are utilized. In these cases the central portion of timber may be completely destroyed by the activities of the larvae.

Zeuzera pyrina L., The Leopard Moth.

The Leopard Moth like the Goat Moth has a wood-boring larva. The adult has a wing-span of about two and a half inches, the female again being larger than the male. The fore-wings are white with numerous blue-black spots; the semi-transparent hind-wings are also white with fainter spots.

The moths lay their eggs from June to August.

The eggs are laid singly in the bark of poplars and many other leaf-trees, trees of small diameter being preferred. During the first season the larvae burrow in a circular direction in the superficial layer of wood; during the second season they burrow in a vertical direction in the inner wood. They form tunnels of between six and eight inches in length. When small diameter stems are attacked, the stems tend to snap off at the point of injury.

The larva is yellowish-white in colour, with black spots. When full-grown it reaches a length of two inches. The larva pupates in a chamber near the surface. When the moth is ready to emerge, the pupa works itself partly through the exit hole, the empty pupal skin may be found in this position.

The excavations of all the wood-boring species facilitate the entry of injurious fungi.

Family: NOTODONTIDAE.

Cerura vinula L., The Puss Moth.

The Puss Moth is common in most parts of Britain. It feeds on the foliage of poplars and willows. The moth is grey in colour, with dark transverse marks and numerous zig-zag lines towards the hind margins of the fore-wings. The hind wings are white in the male and grey in the female. The female has a wing-span of about three inches, the male somewhat less.

The eggs are laid in May or June, and the larvae feed on the leaves; sometimes small trees are almost completely defoliated. The caterpillar is of an unusual shape and colour, primarily green, but with a peculiarly shaped band of a purplish colour passing down

the upper surface. This band has a whitish border and is wider in the central segments. The head is pale brown in colour. The third segment is raised in the form of a distinct hump, and instead of a pair of anal claspers, the last segment is furnished with a pair of tube-like processes, with telescopic tips from which purplish-red whip-like filaments can be protruded at will. These are used to protect the larva against the attack of predators.

When fully developed the larva excavates a hollow in the surface of the bark and constructs a cocoon. Pupation takes place in this cocoon which is well camouflaged. Nevertheless, parasitic insects can locate it and destroy the pupa. If the cocoon is constructed in the bark of a young stem, the stem is weakened and breakage may occur at the wound.

A closely allied species causing similar damage, but of less importance, is the Poplar Kitten, Cerura hermelina Goeze.

Family: SPHINGIDAE.

Smerinthus populi L., The Poplar Hawk Moth.

This species is a large moth flying in mid-summer. It has a wing-span of about three and a half inches, and is very variable in colour, ranging from dove-grey to a light-purplish-brown, with darker bands and transverse lines.

The larvae feed on poplar foliage during July and August, but rarely cause serious damage. They are green with opaque, slanting stripes, the last segment carries a horn. When full-grown they are about three inches long, they pupate in the soil.

The Eyed Hawk Moth, S. occellatus L., also has larvae which feed on the leaves of the poplar species.

Family: LYMANTRIIDAE.

Leucoma (Liparis, Stilpnotia) salicis L. The White Satin Moth.

This species was very prevalent in Britain a few years ago, but recently it has been found only in a few localities. When it does occur in abundance it is a very serious pest, almost completely defoliating poplars.

The moth, which has a wing-span of about two inches, is active during July. It is, as its name implies, white in colour with a satin lustre. One or two-hundred eggs are laid in batches on the stems of poplars or willows, each batch being covered with a substance which, on solidification, forms a protective covering under which the eggs usually over-winter. From April to June the larvae feed on the foliage, at first eating only the surface tissues, but later eating all but the midribs. The larvae grow to a length of one and a half inches. They are dark grey in colour, with pale yellow spots; the head is black and each segment bears three pairs of tubercles with long hairs. The tubercles are bright red. In June the larva spins a loose web, in which pupation takes place; these may be in crevices in the bark, attached to twigs, or among remnants of the foliage.

Order: COLEOPTERA.

Family: CERAMBYCIDAE.

Saperda carcharias L. The Large Poplar Longhorn Beetle.

This species is widely distributed but is some-

what local in its occurrence. In localities where it does occur, it is generally the most destructive insect pest of poplars.

The adult insect is an inch to one and a half inches in length. The antennae are as long as the body in the female and longer in the male; they are eleven - jointed. The body is black but is covered by fine yellowish hairs. The thorax is short and cylindrical; the elytra have prominent shoulders projecting beyond the base of the thorax, and taper rapidly towards the apex. Each elytron has two transverse bands of lighter yellow hairs, a broad band near the middle and a narrower one near the tip.

The beetles are active during June and July, feeding upon the leaves of poplar, out of which they cut irregular holes. The female lays her eggs singly in slits cut in the bark of the lower portion of poplar tree stems. The larvae are legless and of a pale yellow colour. Each is furnished with pad-like protruberences on the upper and lower surfaces; these assist in locomotion.

The larva feeds first just under the bark where it excavates a large chamber in the surface of the wood. A hole is made in the bark through which wood fibres and excrement are ejected. Later the larva excavates a vertical tunnel in the timber, generally extending to upwards of a foot in length. When full grown the larva is nearly one and a half inches in length and over a quarter of an inch in thickness and the tunnel, which is kept clear of litter is maintained at a corresponding diameter throughout. The activities of the larvae can be detected by the heaps of ejected

wood and frass lying at the foot of the infested tree. The life cycle is spread over a period of 2 years.

In old trees, the stem frequently becomes swollen and deformed in a cankerous manner just below the point of attack. Exudations of sap attract Dipterous flies, the maggots of which infest the sap and tend to prevent any occlusion of the holes, which therefore remain open long after the beetle larva has left. Infection by wood-rotting fungi often occurs.

Saperda populnea L. The Small Poplar Longhorn Beetle.

This beetle is very numerous in some localities in the south of England and in the Midlands. Aspen is the chief host plant, but other poplars and willows are attacked.

The beetle measures a little over half an inch, is black in colour, with circular patches of yellow hair on each elytron. The antennae are almost as long as the body and are clothed with grey hairs for two thirds of their length.

The adults are in flight and lay their eggs from early in June, this period lasting for about 6 weeks or longer, depending on the weather conditions. The eggs are laid on the young branches in holes specially cut for the purpose. Round these, the beetle cuts horseshoe-shaped slits in the bark to break the sap flow in the neighbourhood of the egg. During the first season the larva burrows a semi-circular tunnel between the bark and the wood and a gall-like swelling develops around the point of attack. Subsequently the larva bores into the wood and excavates a hole one to three inches in length along the centre of the stem. The insect may cause severe injury to young aspen trees.

One of its most important natural enemies is the woodpecker, and there are also several insect parasites which attack the larvae.

Family: CURCULIONIDAE.

Cryptorrhynchus lapathi L., The Poplar or Willow Borer.

The beetle is a weevil, it is widely distributed but local in occurrence. It normally breeds in alder and willows but sometimes attacks young poplars and is capable of considerable destruction.

The adult weevil is up to half an inch in length, black, with a covering of black, pink and yellowish white scales. The snout is thick and strongly curved; when not in use it is tucked away in a groove underneath the head and thorax.

The adult insect is active throughout the spring; the eggs are laid singly in holes in the bark. The larva, a typical weevil grub, burrows for a time between the bark and wood, sometimes completely girdling the stem, and later, burrows a tunnel two to four inches long in the wood. The adult overwinters in the larval tunnel before emerging to feed on the bark and foliage.

Family: - CHRYSOMELIDAE.

Melasoma (Chrysomela) populi L., The Red Poplar Leaf Beetle.

The adult of this species is about a third to half an inch in length. It has a black head and thorax, but brick-red elytra with black tips. The beetle passes the winter under cover of the soil. The eggs are laid in spring in masses on the undersides

of the leaves, and the larvae appear in about ten days. The larvae are plump, greyish-yèllow in colour, have three pairs of legs, and a row of black tubercles on each segment, and also white lateral projections on the second and third segments. If disturbed, they extrude rows of bead-like glands and secrete an acrid fluid with an odour like bitter almonds.

The larvae, which skeletonize the leaves by eating the surface layers, complete their development in three or four weeks, and pupate attached to the leaves. The adult beetles emerge during July and feed by biting irregular holes in the leaves.

When present in large numbers, this species can often cause severe damage to poplars, which in a young growing tree results in a loss of increment.

Phyllodecta vulgatissima L.) P. cavifrons Thoms.) P. vitellinae L.)	The Blue Poplar-leaf Beetles.

These species may be dealt with together, they are all small bright beetles with a blue-black metallic lustre.

The species are widely distributed and are destructive pests where they occur in great numbers. All cause damage in both the larval and adult stage by skeletonizing leaves, and the beetles cause further damage by gnawing the tender young shoots. The larvae resemble those of Melasoma.

Family: SCOLYTIDAE

Cryphalus (Trypophloeus) binodulus Ratz.
The Poplar Bark Beetle.

This species is a small beetle, less than one-twelfth of an inch in length, black and shining and scantily clothed with short hairs; the antennae and legs are yellowish.

The beetles breed in the bark at the top of poplars suffering from attacks of wood-boring insects and defoliators, where they may precipitate dieback.

Order: HYMENOPTERA.

Family: TENTHREDINIDAE.

Cladius (Trichiocampus) viminalis Fall.,
The Poplar Sawfly.

The Poplar Sawfly is widely distributed and numerous in many localities. The female is larger than the male, being one-third of an inch long compared with one quarter of an inch in the male. The head and thorax are black, the abdomen is orange, the legs yellow, and the wings transparent with light brown veins and stigmata. In the female the antennae are black, in the male brown.

The eggs are laid in slits cut in the leaf stalks of poplar leaves, causing regular swellings on each side. The young larvae are pale green and hairy, later they become light yellow in colour, and when full grown they are orange with black spots. They feed side by side, close together in short rows, on the underside of the leaves, which they skeletonize during the process. There are two generations a year.

Croesus (Nematus) septentionalis L. The Birch Sawfly.

This sawfly has larvae which feed on both birch and poplar foliage. The insect is common in all parts of the country.

The head, thorax, and the first three and last two segments of the abdomen are black, while the intermediate segments are reddish-yellow; the middle and lower parts of the hind legs are broad and flattened. The female has a wing span of about an inch; the male about two-thirds of an inch.

The eggs are laid in slits in the veins of the leaves. The newly hatched larvae are pale-green with black legs; when half grown are green with black and yellow spots, and when full-grown, greenish-yellow with prominent black patches, and are then rather more than an inch in length. They feed on the edges of the leaves, generally with the rear portion of the body held erect. There are two generations a year.

Order: DIPTERA.

Family: CECIDOMYIDAE.

This family, composed of often very minute insects with long antennae bearing conspicuous whorls of hairs, includes a large number of gall-forming species. One species, the Poplar Gall-midge, Diplosis tremulae Wtg. forms galls on the leaf-stalks of poplar and particularly aspen.

Family: AGROMYZIDAE.

Agromyza carbonaria Zett., The Poplar Cambium Borer.

This insect causes damage of great economic

importance, where it is numerous. The eggs are deposited singly in holes made in the bark of poplars during late spring. The larvae bore long irregular burrows in the cambium of the stem throughout the summer months. The larvae are rather elongate, white and tubular in form, with the head pointed, and the terminal segment flattened. On completing their development in the autumn they leave the bark, enter the soil and pupate.

The excavated larval tunnels become infested with bacteria, and the frass and injured tissue becomes discoloured and turns brown. As the growth of the stem proceeds, the larval tunnels are covered with a layer of new wood and become embedded in the timber, a new series of larvel tunnels being formed each year while the infestation lasts.

A cross-section of a previously infested stem shows a number of brown markings around the lines of the concentric growth rings. In longitudinal section the damage shows as small streaks of varying length. These markings, which reduce the strength and value of the timber, are known as pith flecks.

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